THE *Petroleum* Engineer **Management Edition**

Exploration—Drilling—Producing • Refining—Petrochemical—Gas Processing • Oil and Gas Pipelining

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XUM

PESA's Important Role in a Great Industry

The annual convention of the Petroleum Equipment Suppliers Association is being held during the month of June, and this provides an excellent opportunity for reflecting on the benefits that have come to the petroleum industry through the activities of this organization. Born 22 years ago for the purpose of writing a code for the oil equipment industry under NRA, the founders of PESA, upon demise of the Blue Eagle, decided to continue the organization as a means of further working with the national government whenever needed, and as a vehicle for member companies to work on mutual problems.

The wisdom of continuing PESA has long since been demonstrated through two wars and interim periods of peace.

So that no one may be misinformed as to the full scope of its membership, PESA is composed of manufacturers of drilling and production equipment, supply companies, and service companies. Interdependent in their activities and aims, these groups have worked as a team through PESA to improve efficiency in management, technology, service, and manufacturing for the one purpose of accelerating progress in the drilling and producing of oil.

A prime factor in the accomplishments of this manufacture-supply-service group is the extremely high percentage of specially trained scientists, engineers, and technicians that it includes. The ranking is in the highest bracket among large industries. A survey shows the number to be more than 9000, which includes research scientists, technologists, development engineers, metallurgists, technicians, and engineers of many kinds.

Important as the organization has been to its own membership, an accolade should be given for a more generous attitude: To serve the entire industry, not just its membership. An example of the sincerity of this position was the trained personnel made available to the Petroleum Administration for Defense during the war in Korea. Again, during this period of emergency there was great need for statistical data on the special needs for certain critical metals and materials. The monumental task of making such a survey was undertaken and successfully carried out by PESA.

More recently the association has been engaged in a project to obtain statistics on consumption of raw materials by the oil industry. The work is being done for ACMO Division of the Business and Defense Service's Administration, which will act as claimant agency in event an emergency again makes allocation of critical materials necessary.

These are but a few instances of PESA's work but they serve to indicate the extensive and important nature of its over-all activities in an industry whose development depends so greatly on the use of specialized equipment.

We salute PESA on its forthcoming meeting at Banff Springs, Canada.

FRANK H. LOVE.

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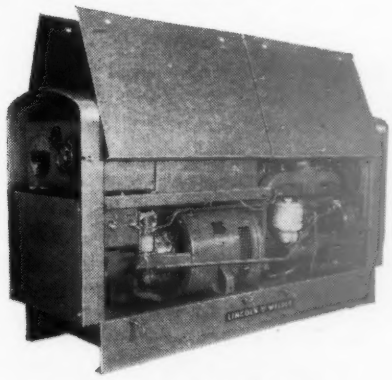

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HIGHLIGHTS ★ ★ ★

Digest of News and Comment

One billion dollars of new capital in Canada will be required in the next five years to develop oil and gas reserves, pipe line, refining and marketing facilities. This estimate was made by W. O. Twaits, of Imperial Oil Limited, who also suggested that input of capital in oil exploration should be expedited with little regard to short-term fluctuations in the demand for finished products.

★ ★ ★

Economical gas air-conditioning systems will be on the market next summer in limited quantity according to Coleman Company, Inc. officials. Unit most likely to be ready for marketing next year will be powered by natural gas internal combustion engine and will be designed with low operating costs and easy maintenance in mind, manufacturers say.

★ ★ ★

Gasoline tax of four cents a gallon, instead of the present two-cent levy, has been suggested by Secretary of the Treasury Humphrey. Such a levy would go far in making the administration's highway program "self-sustaining," Humphrey declared, adding that the plan would "tie firmly together the expenditures on roads and the income which can reasonably be drawn from the users of the roads."

★ ★ ★

Sunray Mid-Continent is getting set for a big exploration program with the recent lease assignment of some 105,000 acres in the Kenai Peninsula area, Alaska. The federal oil and gas rights were obtained by LeRoy H. Hines, a San Francisco petroleum consultant, acting for the company and a California group. Other companies now holding acreage in the same area are Richfield, Standard of California, Union, Ohio, Shell, and General American (Socony).

★ ★ ★

Sabotage to the oil industry has been assigned to 1700 of this country's 22,000 Communists, a guide, "Disaster Planning for the Oil and Gas Industries," warns. The 100-page report, prepared by the National Petroleum Council, outlines a program to follow in case of atomic disaster, as well as for biological and chemical warfare. Readiness and proper security measures were suggested, although the book also warned that "there may be no time to prepare."

★ ★ ★

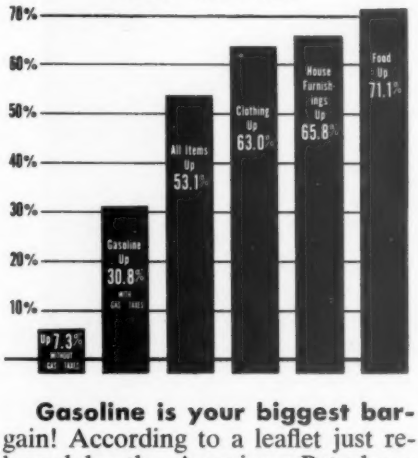
Despite increased demand and completion of many new prolific producers, Louisiana will trim its June crude proration by 48,000 bbl daily. Low allowable pattern set in May by the Texas Railroad Commission will be even lower for June and July. June proration has been set for a 15-day schedule at about 3,042,760 bbl daily, one producing day and 64,820 bbl per day less than the May allowed production. A lower flow, 2,975,541 bbl daily based on current production, will be permitted to Texans in July. A build-up of new wells in the coming month may raise this figure.

★ ★ ★

Natural gas prices in the Texas Panhandle have increased nearly 14 per cent during 1954, the state Railroad Commission has reported. Gas brought an average of 8.7116 cents per 1000 cu ft during the last 6 months last year. Price of the gas a year earlier averaged 7.6566 cents.

★ ★ ★

Cost of Living Comparison 1954 vs. 1925



Gasoline is your biggest bargain! According to a leaflet just released by the American Petroleum Institute, the retail price of gasoline, less taxes, have increased only 7.3 per cent since 1925. Taxes, however, rose 250 per cent. "Gone are the days of the dollar watch, the penny postal card and the $500 car, but what of the price of gasoline?" the leaflet questions.

Sun Oil Company officers and crewmen of the tanker S. S. Louisiana Sun have been honored for a daring sea rescue of three fishermen, in stormy seas early this year. Commandant of the United States Coast Guard, Vice Admiral A. C. Richmond presented a scroll and pennant on behalf of the National Safety Council and American Merchant Marine Institute to Sun Captain Jacob R. Lockwood for the feat of seamanship.

★ ★ ★

A special investigation to determine the adequacy of West Coast oil supplies in case of war, headed by Representative Herbert of Louisiana, will begin early in June. Study of the situation by a House subcommittee has been pushed by Representative Short of Missouri, and backed up by the House armed services committee.

★ ★ ★

Colorado Supreme Court has ruled that the Colorado Oil and Gas Conservation Commission has exceeded its authority by its order for reinjection of natural gas into the Rangely oil field. The court stated that the state legislature has power to legislate on such matters or to delegate the authority to the commission, which the body did not do in the 1951 law establishing its rules.

★ ★ ★

Congress will probe into existing tax laws, and will focus attention on the present oil and gas depletion allowance. The study will be headed by Rep. Wilbur D. Mills (Arkansas) of the joint economic subcommittee. Although Mills has favored the depletion rate, actual work will be done by a group outside the industry.

★ ★ ★

Secretary of Interior McKay has named Harry W. Bass, Dallas, Texas independent oil operator and president of the Texas Mid-Continent Oil and Gas Association, as his special aide for the Fourth World Petroleum Congress. McKay is an official U. S. delegate, with Texas Railroad Commissioner Ernest O. Thompson and Ambassador-to-Italy Clare Boothe Luce, for the Rome, Italy, international gathering June 6-16.

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Standard of Ohio raised retail prices on regular and premium grade gasoline a cent a gallon, bringing the price back to last year's level in the Cleveland area. Price of heavy marine diesel fuel has been cut eight cents a barrel at Atlantic and Gulf ports by Esso Standard.

★ ★ ★

Assistant Attorney General Barnes announced in recent testimony before a house sub-committee that no anti-trust clearance has been given to any oil company taking part in the Iranian oil consortium. The statement conflicts with news reports and a booklet published by Jersey Standard which said that American companies had been encouraged to participate and had been given an official promise of immunity from anti-trust law prosecution.

★ ★ ★

Government has virtually completed its sale of synthetic rubber plants with the cash receipt of $81,595,072 for three Port Neches, Texas, rubber plants recently. The government originally had 27 of the plants up for sale as surplus property.

★ ★ ★

Texas Gulf boundary is again in question, this time by the Interior Department which has recently asked for funds to survey the area. Although there is still a difference of opinion as to whether the line lies three geolographical miles or three marine leagues (about 10 miles) from the shore, the exact boundary must be done by survey methods. Coinciding with the Interior Department request is news that the Justice Department is winding up its study of the Texas and Louisiana boundary question, which is said to "leave room for lawsuits" over offshore oil ownership.

★ ★ ★

Socony Mobil Oil Company has been accepted as the new corporate name of Socony-Vacuum, and all refined products of the company will be marketed under the "Mobil" brand label. Since the merger of the Standard Oil of New York and the Vacuum Oil companies 24 years ago, the company has grown to be one of the largest producing and merchandising organizations in the world.

The Sunray and Mid-Continent merger, effective on May 16, established the new firm as the fifteenth largest domestic oil company, on the basis of fixed assets only. Figuring working capital also, the company would rank thirteenth. The merger is second only to the Socony-Vacuum union in 1932.

★ ★ ★

World's most northernmost refinery, located near Turku, Finland, will be constructed by American engineers. The refinery, which will process 18,000 bbl of Middle East and Black Sea area crudes, will be controlled by the Finnish government, under the firm of Neste Oy. The installation will supply a substantial part of Finland's petroleum requirements.

★ ★ ★

Domestic petroleum industry has been hurt "in varying degrees" by the continued increase in crude oil imports, according to a National Petroleum Council approved report made public recently by a committee headed by Jake Hamon. Extent of the detrimental effect is difficult to estimate due to fluctuating petroleum demand, inflation, lowered excise import taxes, and increased development outside the United States, the report notes.

★ ★ ★

Severe shortage of engineer college graduates this spring has increased expected starting salaries to $400 per month and has forced companies to increasingly high-pressure recruiting programs. The 200 graduates of Columbia School of Engineering, for example, are being sought by 260 companies. Many students are being offered jobs for 1956, 1957 and 1958. American industry needs 30,000 new engineers this year, and has only 21,500 graduates to fill the openings, according to a Columbia University release.

★ ★ ★

Legislation to decontrol prices of natural gas produced by independents is expected to be approved shortly, according to Senate Leader Lyndon Johnson of Texas. Specific bill favored by Johnson has been offered by Sen. J. W. Fulbright of Arkansas; it is being processed by the Senate Commerce Committee.

"Marked changes" in the refining industry will be evident by 1965, according to A. L. Lyman of the California Research Corporation. By that time, Lyman predicted to a group of API refiners, Americans would be driving cars with gas turbine engines, demanding 100-octane fuel, and consuming over 11,000,000 barrels of petroleum daily. Present demand per day is about 7,000,000 barrels.

★ ★ ★

Oil industry now leads all other U. S. industries in granting "fringe" benefits to its workers, according to findings of an API survey just completed. The survey numbered 1,650,000 oil workers, representing an increase of 440,000 since 1946. One out of every 38 workers in the United States is now employed by the petroleum industry.

★ ★ ★

The United States Attorney General has been appointed by the Senate to act as watchdog for the Interstate Oil Compact. Action came with the approval of a bill which requires the Attorney General to file an annual report determining any price-fixing or monopolistic intent of oil states using the agreement. The bill also granted a four-year extension of the compact.

★ ★ ★

Iricon Agency, Ltd. has been formed by nine American firms to extend this country's interest in the Iranian oil consortium to 14 companies. The new companies which will have crude production, refining, and exports rights in Iran include American Independent, Atlantic Refining, Hancock, San Jacinto Petroleum, Signal Oil and Gas, Sohio, and Tide Water Associated.

★ ★ ★

In, 1954, Americans operated 58,589,863 cars, trucks and buses—2,300,000 more than the year before, according to a late Bureau of Public Roads report. To run this fleet, motorists used 44 billion gallons of gas and other fuel, with the states taking in almost $2,300,000 in motor fuel taxes, discounting tax-exempt 6.2 billion gallons used for farm, aviation, industrial and government usage.

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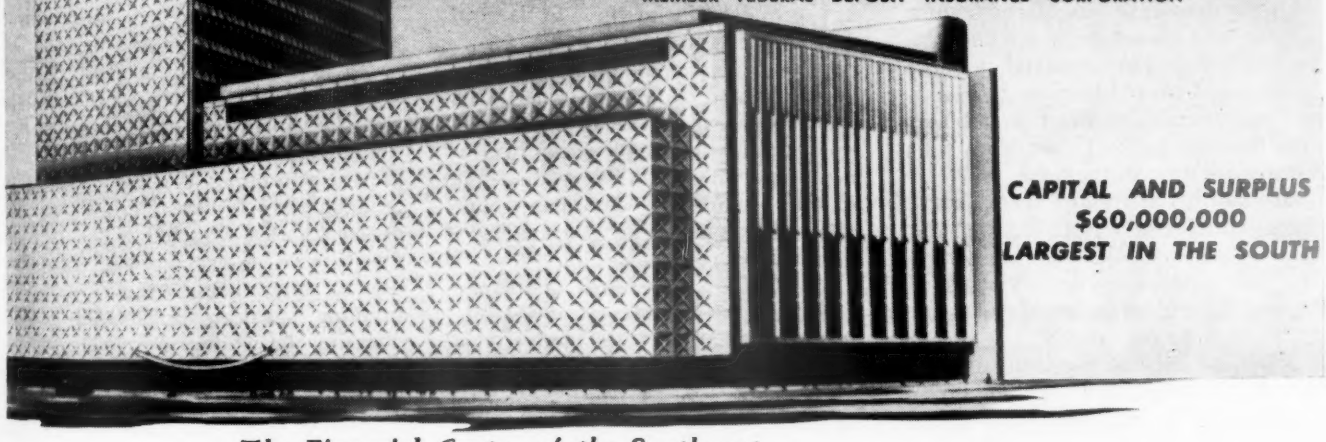

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Petroleum Profile

Walter S. Hallanan

IF Walter S. Hallanan, president of Plymouth Oil Company, chairman of the National Petroleum Council, and a top-notch figure in national politics, followed the accepted pattern of a dynamic modern business executive, he would find frequent relaxation on the golf course, in a trout stream, at the bridge table, or on an occasional big game hunt in Africa.

But Walter Hallanan is not one to follow a script written for him. He has not had golf clubs or playing cards in his hands for more than 25 years; he probably would not know a trout from a bass and the only big game he ever saw were in zoos and circuses. He does not even sit on a park bench. In short he is the despair of newspaper feature writers, who cannot get him within the focus of their pre-conceived notions. "I suppose I am old-fashioned," Hallanan said when asked about his hobbies, "but the only hobby I have is my job. I just work most of the time."

Most of his many jobs were undertaken with the understanding that the responsibility would be temporary but, once installed in any new position, he has become as frozen there as oil prices were during the war.

When he became president of Plymouth Oil Company at the time of its organization in 1923, he had not the faintest idea that he would still be its executive head 32 years later, or that under his leadership the small wildcatting enterprise would become a highly successful independent oil company.

Five years later he became a member of the Republican National Committee for what he thought would be a single four-year term. Today, 26 years afterward, he is still the Republican National Committeeman from West Virginia. He is the vice chairman of the committee and its second oldest member in point of service. Elected temporary chairman of the party's National Convention in Chicago in 1952, he began the most permanent "temporary" chairmanship in the national political history, presiding during three of the four days of convention sessions.

When the National Petroleum Council was created in 1946 to undertake a trail-blazing experiment in the field of government-industry cooperation, members choose the tall West Virginian as their temporary chairman. Nine times since succeeding councils have unanimously re-elected him.

Along the way, this gentleman picked up the presidency of the Big Lake Oil Company, the active vice presidency of Republic Oil Refining Company, Republic Pipe Line and Duval Pipe Line Company, as well as directorships in those companies and also in Melben Oil Company, National Cylinder Gas Company and others.

Walter Hallanan is the son of a West Virginia country doctor of the old school, who in 50 years of practice never sent a bill to a patient. It was natural that the young Hallanan should attend Morris Harvey College, a Methodist institution located in his native Barboursville. He was graduated when 14 years old and went to work as a cub reporter on the *Huntington Herald;* at 18 he was managing editor.

When he was a lad of 13, Walter was a page in the West Virginia Legislature and there his inherited flair for politics quickly developed. In 1912 he took leave of absence from his newspaper to handle publicity for Dr. H. D. Hatfield in the latter's successful campaign for the governorship of West Virginia. The young managing editor never again returned to journalism. Dr. Hatfield appointed young Hallanan as secretary to the governor, the youngest man ever to hold that office in West Virginia. Less than four years later he became the most youthful holder of the office of State Tax Commissioner, in which position he served a six-year term. Soon after the conclusion of that service he was elected to the West Virginia Senate, in which as chairman of the powerful Finance Committee, he was one of the two majority leaders.

It was while serving as State Tax Commissioner that Hallanan first developed an interest in the oil business. He took a "flyer" on a wildcat well being drilled by the late Colonel A. E. Humphries of Denver, a West Virginia native. The well was a producer and Hallanan made investments in other operations of Colonel Humphries.

Mr. and Mrs. Hallanan and their daughter, Elizabeth, live in Charleston, West Virginia, where the daughter is a successful attorney and a member of the State Board of Education. A son, W. S. Hallanan, Jr., lives in Pittsburgh, and is associated with Republic Oil Refining Company. The son and his wife are the parents of the three Hallanan grandchildren. Hallanan commutes between Charlestown and Pittsburgh in a private DC-3 airplane, which he also uses in getting about over the country fulfilling speaking engagements and directing the affairs of his companies.

"He can't keep this up forever," Hallanan's associates frequently say. They have been saying the same thing for the last 20 years.

The
Petroleum Engineer
June 1955

EXCLUSIVE

The Boltana well in the province of Huesca

P 139.95

Petroleum Achievements in Spain

Mario Alvarez-Garcillan and Eduardo Recasens

RATHER encouraging results have been obtained in Spain through scanty prospecting for petroleum reserves since the beginning of this century. This fact together with favorable results attained by some other Mediterranean countries in recent years, is a good argument that exploring for oil in Spain is not a crazy business. Nevertheless, at this time Spain's petroleum economics consists of products and raw materials imported from abroad.

It is the strategical situation of Spanish Territories that may give the country a special place in the international traffic of petroleum products. Spain, with its insular provinces and its African territories is a transatlantic crossroad and because of this geographic condition it might perform, and in fact is beginning to, a particular role in the international oil business.

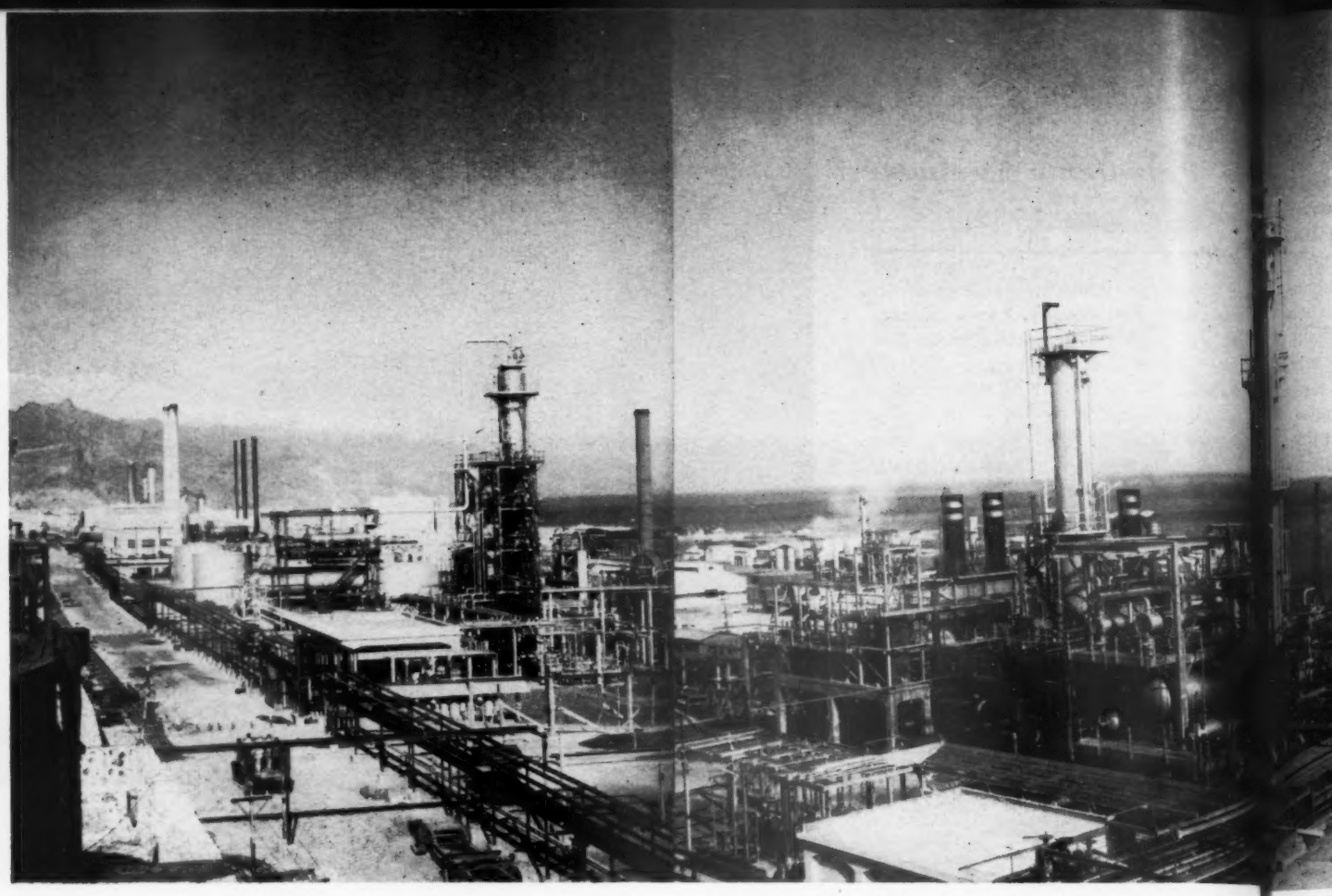
Marketing of all petroleum products in the Spanish mainland and in the Balearic Islands is a government monopoly. This monopoly includes gasolines, middle distillates, and residual fuel oils, which are imported and traded solely by a Government-sponsored concern named Compañia Arren Dataria del Monopolio de Petroleos, S. A. (Campsa). Other products, such as lubricants, asphalts, paraffin waxes, etc., may be imported by private firms within certain regulations, provided the Monopoly has granted the necessary authorization.

Until a few years ago, the Monopoly was the sole concern entitled to install and operate refineries in the areas covered by its jurisdiction, that is continental Spain and the Balearic Islands. Private firms, however, could operate in those territories juridically controlled by the Spanish Government, but not covered by the Monopoly. These are the Canary Islands, Spanish Morocco, the territories of Ceuta and Melilla, and generally, all the Spanish Possessions in Africa. During the last decade some changes have made the exclusive regulations less rigid so that private capital is now allowed to operate refineries inside the monopolized areas, when in partnership with Government-supported concerns.

The foregoing gives a special character to the oil business in Spain. Development of oil is reported below in these divisions: 1. Prospecting and drilling; 2. Refining; 3. Markets, and 4. Transports.

After a brutal civil war and consequent political and economic isolation, Spain is beginning to gain strength and hope. Petroleum potential is promising enough to attract outside interests and refineries almost meet the country's demand. Its geographical position makes Spain a crossroad in oil trade.

XUM



Panoramic sight of Cepsa's Teneriffe Refinery showing the

1. PROSPECTING AND DRILLING

Searches for natural petroleum resources in Spain have been carried out in three quite different stages. These differences may result from political and legal causes rather than for technical reasons.

First stage

From the beginning of this century until 1936, when the Spanish Civil War broke out, is the first period of development.

First wildcat in Spain was drilled in 1900 near the little village of Huidobro (province of Burgos). This hole, reaching 1600 ft in depth, was dry. In subsequent years, a total of 11 wells were drilled over the whole Spanish Territory. Of all these drillings, the Huidobro included, four gave absolutely negative results, four others showed petroleum traces, two produced some gas and one had to be shut down owing to mechanical trouble. The deepest well was the one drilled at Gastiain (province of Navarra) in 1952 (5300 ft).

Almost the whole of the above drillings were performed without previous detailed geological studies. Notwithstanding, half of them gave some signs which in a way may be qualified as positive.

In 1927 and 1929 respectively, the two first national petroleum firms having a real importance were founded in Spain. They were the already refered to Campsa and Compañia Española de Petroleos, S. A., usually called Cepsa.

Though Campsa was incorporated with private capital, its main purpose was to exploit, by legal concession of the Spanish Government, the recently created monopoly.

Cepsa, when instituted, had the immediate and exclusive purpose of establishing crude oil properties in foreign countries which would feed the Spanish market ruled by Campsa, either with products refined by other concerns or through the refining operations that Campsa would be able to perform at its own future Spanish refineries. Owing to the circumstances, this purpose was dropped as it will be seen.

Among the goals to be attained when the Monopoly was established in Spain the most outstanding was that of developing domestic petroleum reserves. A good effort was made by Campsa to this end throughout the first years of its life. Simultaneously,

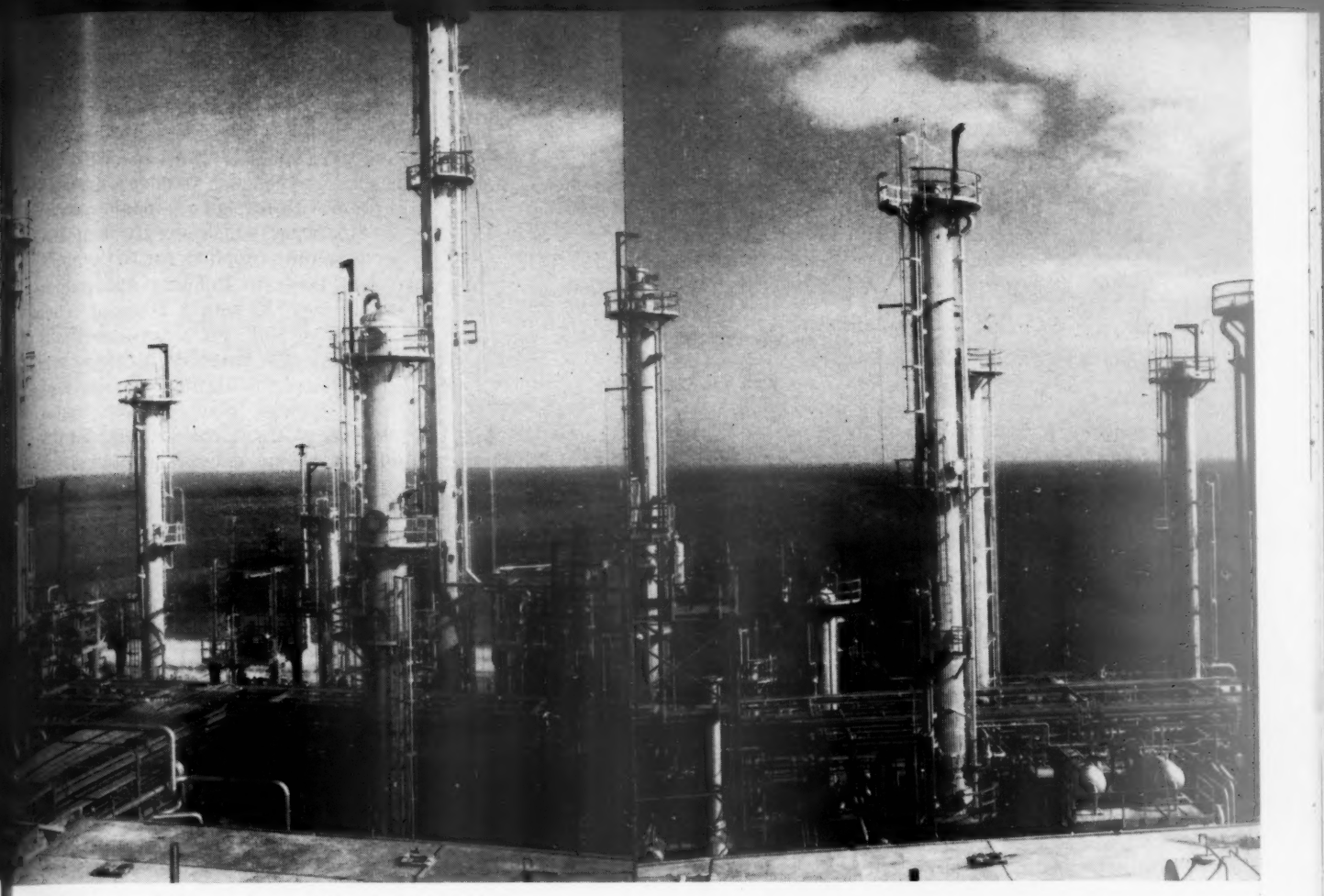
The Authors

E. Recasens

Alvarez-Garcillan

Eduardo Recasens began working in the Teneriffe Refinery in 1937 and remained three years. In 1947 he was graduated as an industrial engineer from the Barcelona School. During 1948 he spent several months in the USA as a student in the Columbia University, visiting some of the major refineries and oil fields and later studying petroleum processing with the UOP staff. In 1949 Recasens resumed work with Cespa at the Teneriffe Refinery, then was promoted to headquarters in Madrid where he is assistant head of the Technical Department.

Mario Alvarez-Garcillan was graduated as an industrial engineer in 1936 and in 1939 he joined the Cespa staff, working at the Teneriffe Refinery for 2½ years. He cooperated also in the construction of the Cartagena Refinery. Since 1949 he was in charge of Cespa's technical department in the Madrid office. During his 16 years of activity in the oil industry he has written many articles published in Spanish reviews and has presented papers in the International Congress.



new Platformer and Udex unit operating since last February

Cepsa realized the high interest this task involved and took preliminary steps to achieve prospection plans parallel and complementary to those of Campsa. To this end, by 1934 a geology staff jointly formed by Cepsa and Socony-Vacuum began a survey campaign in some Spanish areas in which preparatory geological studies were outlined.

Unfortunately, the political circumstances prevailing in Spain during the period 1929-1936, prevented proceeding with those works and consequently drilling operations were indefinitely postponed.

Second stage

From 1936 to 1953 the only active years were those between 1939 and 1953. During the Civil War (1936-39) either with products refined by other concerns or through the refining operations that Campsa would be able to all the Spanish economics were out of control.

Taking as a basis the preliminary work performed in 1934, Cepsa and Socony-Vacuum incorporated in 1940 a fifty-fifty concern named Compañia de Investigacion y Explotaciones Petro Liferas, S. A. (Cepsa). The immediate objective of this company was to undertake wildcatting at once, but owing to restrictions resulting from the development of World War II, operations ceased and only in 1947 were finally carried out when the first modern drilling rig purchased in the United States arrived in Spain.

Holes drilled, their depths, and final results attained during all those years are listed below:

CAMPSA			
1947–49	Four small diameter exploratory drillings with a maximum depth of 2620 feet.	Burgos	Traces in Wealden sands
1949–50	Zamanzas No. 5 (4150 feet)	Burgos	Traces
1950–51	Dobro (5000 feet)	Burgos	Dry
1951–52	Zamanzas No. 6	Burgos	Impregnated Limestones
CIEPSA			
1947	Oliana (7600 feet)	Lerida	Dry
1948	Burgo de Osma (7200 feet)	Soria	Dry
1950	La Marina (5300 ft.)	Alicante	Dry
1951	Rojales (5200 feet)	Alicante	Dry
1952–53	Boltana (7000 feet)	Huesca	Dry

Third stage

In December 1952 the Spanish Government passed a law by which exploratory rights in all Spanish Territories not yet bound to previous concessions, were reserved for Government-sponsored research plans. This meant no private companies should be granted further concessions and only those in Spanish Territories before December 1952 could operate.

This law set up a very definite landmark for prospecting in Spain and has created an uninviting situation to the firms which in late years courageously risk their funds in such a venturous enterprise as oil exploration.

After this curtailment, Campsa has drilled no more. Cepsa has drilled the Boltaña No. 1 well, in an eocene structure of the province of Huesca, south of the Pyrinees. This drilling was abandoned after a depth of 7000 ft with negative results.

By late 1952 Ciepsa worked out a sort of joint venture with the German firm Dielmann Bergbau to carry out an important plan of seismic geophysical prospecting. This group has recently imported German-made drilling equipment suitable for depths up to 13,000 ft.

This Ciepsa-Dielmann association is presently drilling at Zuñiga (Navarra) with its new equipment. Meanwhile the Ciepsa's old American rig is working at Apodaca (Alava). A team of Spanish and German geologists is now studying geologic and tectonic features in Ciepsa's concessions. The seismic reflection equipment of Ciepsa-Dielmann is steadily working, and it is expected that in a short time other similar equipment will be imported from Germany.

The Instituto Nacional de Industria (INI) which is the Government-sponsored concern which entered in the exploration field as a consequence of the 1952 law, incorporated in 1953

XUM

Bunker station of Cepsa at the port of Centa, Spanish Morroco

the company named "Valdebro" which was formed by INI subsidiary Empresa Nacional Adaro jointly with a group of USA* firms.

This company has carried out a geologic survey all over the Ebro Valley in the northeast of Spain, followed by a seismic survey which has been carried out by the American partners. This firm drilled the Marcilla well in Navarra, which reached a depth of 11,200 ft with no positive results. In July 1954 the same company started exploratory drilling at Oncala (province of Soria) in order to investigate the Wealden and Jurassic formations.

During 1954 Adaro has drilled another hole at Castelfrío (Soria) which was dry at a depth of some 6000 ft. Always for exploratory purposes Adaro has drilled during 1954 some wildcats in Baeza, Villanueva de la Reina, Bailén, Chiclana, etc. This firm is, by now, starting a new drilling in San Lorenzo (Cuenca) where a geophysics set and six geological crews are operating. By early March 1955, Adaro got some methane production in Ecija. The importance of this strike has not yet been made public.

Besides the above mentioned concerns there is a series of small firms or groups taking advantage of some small concessions. Most of them are in Catalonia but in general all are inadequately fitted.

It may be deduced from the foregoing that up to the present the oil operations in Spain are insignificant when compared with the campaigns in other European countries such as France and Italy. The fact is that in these countries oil development in a few months has surpassed what has been done in Spain in the last 25 years.

Spain has always been an oil-potential land. Besides a great number of seepages it includes in its territory the Ebro River geosyncline, which is considered to be one of the most important in Europe with its 60,000 ft mesozoic and 15,000 ft marine tertiary. In geologic structures similiar to these in Spain, the Ragusa field in Sicily was discovered in 1954 and the Parentis well, close to the border between France and Spain, came into production recently.

These two discoveries along with some other even more recent in Italy form a circle around Spain. Commencing in the oil and gas fields in the south of France and in Italy, it extends through Sicily to Oran, Argel, French Morocco, and closes at Portugal with its small production at Torres-Vedras.

It is evident that finding oil in Spain is only a matter of assiduity in the effort and exhaustiveness in geological and geophysical research. Association or coexistence of official and private interests in this field may prove useful when they support and compete with each other. Spain may be on the way to take a place among the European oil producing countries. Most of its natural conditions appear to be favorable.

2. REFINING

As already explained, the main purpose of Cepsa's creation in 1929 was based on the need to secure supply of raw materials for the petroleum industry to be subsequently developed in Spain. By that time, it appeared that Cepsa's destiny would have to be limited to that of being only a crude oil seller in the Spanish markets.

A few months after its foundation, Cepsa was compelled to extend its affairs to undertaking construction of the Teneriffe (Canary Islands) Refinery. In this way Cepsa was getting prepared to market products in Spanish Territories free of monoply control (Spanish Morocco, Canary Islands and Spanish Guinea), in competition with foreign companies, mainly American, which up to then had been the only suppliers for those areas.

The Teneriffe Refinery was put on stream in 1930 with a nominal crude capacity of 5000 bbl a day, essentially consisting of a crude vis breaking unit with related auxiliaries such as tank farms, treating plant, power house, pumping stations, etc. During depression years the products obtained in the refinery were sold with some difficulty in the Canary Islands and Spanish Morocco markets and also to the monopoly for the Spanish mainland.

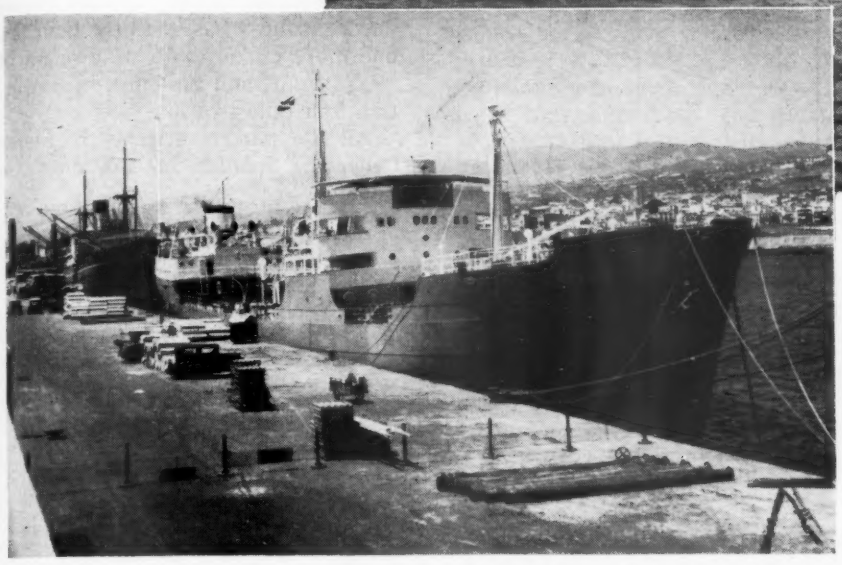
In 1936 the beginning of the Spanish Civil War brought about many hardships to the country. The role of Cepsa in supplying petroleum products became more important in view of the fact that the majority of the foreign companies refused to continue supplying Spain.

The end of the Spanish Civil War was shortly followed by the beginning of World War II, so difficulties in petroleum supplies continued. The situation became critical in many instances thus creating big problems in a Spanish economy already in trouble. To alleviate the situation the Spanish Government considered it was necessary to install a new refinery on Continental Spain and consequently asked Cepsa's technical assistance to carry the project through. Cartagena, in the south of the Mediterranean coast of Spain, was selected as best location for the new refinery. Military events prevented completion of the refinery until the end of the war but the refinery had its auxiliaries nearly finished and ready to go, lacking only the main refining facilities.

To complete and run the refinery a new private enterprise was formed in 1949 with the name of Refineria de Petroleos de Escombreras, S. A. (Repesa). The capital stock of this corporation was contributed 52 per cent by INI, under Government control, another 24 percent by Caltex and the remaining 24 per cent by Cepsa. The new associated corporation could finally complete the refinery and put it in operation in 1950 with a nominal capacity of 5000 bbl a day.

Moreover, the INI has recently decided to build a refinery in Puertollano, an inland town in the province of Ciudad Real. The capacity of this refinery will be 15,000 bbl a day and crude oil will be supplied through a pipe line from one of the nearest

*Including Caltex, General American.



The Almisante Vierna, right, 15,000 tons dw tanker owned by Elcano. Below, 55,000 dw tanker Ciudad Rodrigo owned by Cepsa

ports. To finance the refinery construction the INI has obtained a credit in foreign currencies against a crude supply contract from Caltex and Shell companies.

Since their on-stream day, both the Teneriffe and Cartagena refineries have been expanded several times to increase capacity and modernize facilities.

The Teneriffe refinery is at present producing all grades of petroleum products ranging from light LPG fuels, through motor and diesel oils, kerosine, lubricants, paraffin waxes, fuel oils, etc., to heavy asphalts. The Cartagena refinery is commencing its lubricant manufacture and will consequently offer the same range of grades as the Teneriffe refinery.

The overall capacity of these two Spanish refineries comes close to four million tons per year. With them the actual requirements of the Spanish markets for some products are amply covered. Such is the case for motor fuels and asphalts so there is no need to import any of them.

A platforming and Udex unit was put on stream in the Teneriffe refinery in February. With this unit the quality of the gasolines offered by Cepsa to its markets has substantially improved. The platforming section of the new unit was the first one to be constructed outside the American continent and has been the fifth erected in Europe. The Udex section is the only existing one outside the USA and has been the fourth built in the world.

With these two in one unit Cepsa is now in a good position to produce and market aromatics, i. e. benzene and toluene, as raw materials for petrochemicals.

Repesa has also recently contracted for a platforming unit to be installed in the Cartagena refinery. After erection of this unit quality of motor fuels in Spain will be able to keep up with the present trends, at least for premium grades.

It is very interesting to point out that owing to the strategical location of the Teneriffe refinery a substantial part of the heavy fuels produced in it can be sold as bunker fuel to international sea lines like those between the European countries and their African colonies or between Europe and the Americas.

The international bunkering market is at present absorbing almost one half of the total production of the refinery. The refinery is also operating on behalf of foreign companies under processing agreements. This is why the Teneriffe petroleum products have reached countries so far away from the Island as England, Sweden, South Africa, Turkey, Greece, Portuguese Occidental Africa and Madeira.

Through a recent agreement between the Portuguese and Spanish Governments, Cepsa will soon supply petroleum products to Portugal, in this way developing a new market.

3. MARKETS

As previously said traffic of petroleum products is under monopoly control in Continental Spain and Balearic Islands.

In these areas distribution and marketing of petroleum products are performed by the corporation holding the monopoly rights, which is Campsa.

In the other Spanish territories marketing of petroleum products is free but remains ruled by the regulations in force for foreign currencies traffic. This situation makes the Teneriffe refinery the only source of petroleum products for domestic needs.

The private national and foreign distributors marketing in these areas are therefore, buying from Cepsa all the products they sell to domestic consumers.

The foreign companies having bunker facilities in monopoly-free Spanish Territories have been granted permission to import their fuels with no limitations but one, that of payments having to be in certain currencies. Of the currency benefits obtained from this trade a small part has to be given to the Spanish Government against payment of the corresponding equivalent in pesetas.

Bunkering in Santa Cruz de Teneriffe and Las Palmas (Canary Islands) and Ceuta (Spanish Morocco) close to Gibraltar, has developed a considerable sea traffic through these ports. Cepsa is the only bunker supplier in Teneriffe while in Las Palmas bunkering is also done by some foreign companies like Shell, Texas, Socony-Vacuum, Esso Standard and Cory Bros. In Ceuta besides Cepsa there is another bunkering Anglo-Spanish firm with the name Ybarro la, S. A., while a third company under the name of Compañia General de Corbones, S. A. is at present constructing additional bunkering installations.

The consumption of liquid fuels in Spain is at present entirely free, the last restrictions having been taken out some three years ago.

The quality of motor gasolines is improving fairly well since the Teneriffe

XUM

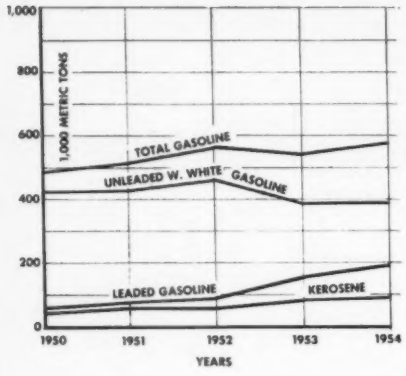


FIG. 1. Total consumption of light refinery products in Spain's mainland and Spanish territories

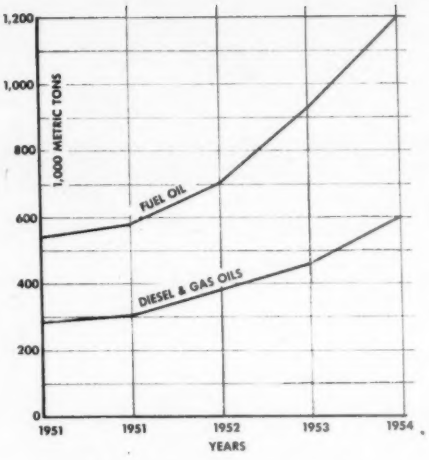


FIG. 2. Total consumption of heavy products in Spain's mainland and Spanish territories

refinery Platformer was put on stream last February. It is expected that by next summer a new extra grade of gasoline with 80/86 O. N. will be marketed throughout Spain.

A low level of unleaded gasoline with 60 to 65 O. N. F2 will have to be maintained for some years in order to supply the very old types of engines still running in the country. These old engines are still in a considerable number although newer types are being imported in limited quantities under commercial treaties with some European countries. Production of cars and trucks in Spain is still very small although some new factories have recently started to manufacture different types of economical popular cars.

In the entire Monopoly areas, moreover, a policy of modernizing storage, transportation and distribution facilities is being followed which improves the quality of products handled.

The consumption of petroleum fractions is following closely the curve typical in all countries being industrialized.

As a direct consequence of the taxes on motor gasolines the consumption in the country has not changed very much the last years. On the contrary, consumption of distillate and residual fuels shows a very important and steady increase. Thus the Spanish refineries are more than sufficient to provide for Spanish gasoline needs, but demands of middle and heavy fuels in the domestic and bunkering markets are more than the actual capacity of the two main Spanish refineries. The balance must be imported.

Fig. 1 and 2 show total consumption curves of light and heavy petroleum products in Continental Spain and Spanish territories during the 1951 to 1954 period. These curves show clearly the increasing slope of the heavy products consumption curves whereas the consumption of light products remains almost unchanged during the same years.

4. TRANSPORT

Main sources of crudes for Spain, as for all other European countries, is the Middle East. Nevertheless, owing to the geographic location of this country it is still possible to refine Caribbean crudes under fairly economical conditions.

Imports of finished products are decreasing in recent years owing to the considerable expansion of the domestic refining capacity. Imported products, however, must balance the deficits in middle distillates and residual fuels. These are supplied by European and Caribbean refineries.

According to the above petroleum marine transport covers the following ends:

Carrying crudes from producing zones to domestic refineries.

Carrying finished products from domestic refineries to domestic coastal bulk stations.

Carrying finished products from foreign refineries to domestic bulk stations.

Marine transport of both crudes and finished products is getting more and more nationalized thanks to a rapid and substantial increase of the Spanish tanker fleet, which has taken place in the last few years.

Campsa owns twenty-eight tankers, from which twenty-three have an individual tonnage of more than 2000 tons dw. Besides this, four units with 9000 tons dw each are being built in Spanish shipyards for this concern. During 1954 Campsa's fleet transported some 2,400,000 tons of finished products.

Cepsa owns six tankers with a total dw of some 50,000 tons. It has under construction in a Spanish yard a seventh one with a deadweight of 18,400 tons. Cepsa's fleet carried during 1954 450,000 tons of crude.

Besides these there are some other owners in Spain among which the most important is Empresa Nacional Elcano which has in service two tankers of 15,000 tons each. These units are the most modern in the Spanish tanker fleet. Elcano has recently launched one more tanker, with deadweight of 19,000 tons, and has under construction four others of like size.

All the tankers actually registered under the Spanish flag are shown in Table 1.

TABLE 1. Spain's tanker fleet.

1. Actually sailing under the spanish flag.

OWNER	TANKERS		DEAD WGT TONS
CAMPSA	7	10,600	74,200
	7	8,000	56,000
	4	6,000 (Avg.)	24,000
	2	4,000	8,000
	3	2,000	6,000
	2	1,000	2,000
	1	500	500
	1	400	400
	1	200	200
CEPSA	1	12,000	12,000
	1	11,000	11,000
	1	10,550	10,350
	1	8,500	8,500
	1	5,500	5,500
	1	1,500	1,500
ELCANO	2	15,000	30,000
	1	19,000	19,000
Total	37		269,350

2. Presently under constructon in Spanish shipyards

OWNER	TANKERS		DEAD WGT TONS
CAMPSA	4	9,000	36,000
CEPSA	1	18,000	18,000
ELCANO	5	19,000	95,000
Total	10		149,000

Apart from the above referred units there are others under foreign flags which are permanently or semipermanently in the service of Spanish refineries.

Plans to increase the Spanish tanker fleet are now under way, in order that domestic needs will be covered entirely with Spanish-registered tankers.

In some Spanish official and financial circles opinion favors enlarging the oil commercial fleet more than domestic demands in order to enter international freight markets. This would create a source of foreign currencies and help balance foreign exchange. The geographical position of Spain in Western Europe and the seaworthy tradition of this nation of navigators support this plan.

Inland transport has many difficulties because of the geologic constitution of the Iberian peninsula and its still imperfect communication system.

Up to now, the transport of all the petroleum products toward the internal markets is by railroad and by highway as there is no pipe line in service. Campsa is the firm that operates this transport system, which presently has 1150 tank wagons with a capacity variable between twenty and fifty tons and 525 tank trucks of five to fifteen tons capacity. * * *

Exploration, Drilling, Producing

Oil Doubly Hard to Find

Hitting at recognition of the replacement cost factor by oil accountants, IPAA reports that twice as much drilling is necessary to locate and process a barrel of oil as in the years 1937-41. With about 70 per cent of the domestic production coming from wells drilled before World War II, it will be years before the effect shows up in company records—unless current operations are planned with replacement costs in mind.

★ ★ ★

Reinecke Wells Sold

Thirteen wells in West Texas with a combined allowable of 1591 bbl daily, have been bought by Producing Properties, Inc., for a cash consideration of about $5,000,000. The wells, in the Reinecke Pool of Borden County, were sold by J. D. Leftwich, et al. Engineers have estimated the total reserves of the properties to exceed 5,500,000 bbl net. Purchase negotiations were handled by the San Juan Exploration Company.

★ ★ ★

Offshore Sale Set

Third sale of oil and gas leases in the outer continental shelf of the Gulf, covering 674,095 acres, has been announced by the Interior Department. The department stated that most of the 594,666 acres nominated by the oil and gas industry March 25 are included. The acreage up for sale is off the coasts of Texas and Louisiana.

★ ★ ★

Shell Group Sets Record

Shell Oil's New Orleans exploration department has been commended on a safety record of more than 1,000,000 man hours without a lost-time accident in the last 21 months. The group of about 300 persons work primarily in field parties on powerboats, scows, swamp buggies, helicopters, cars and trucks. Last disabling injury was on July 16, 1953.

★ ★ ★

New Homes for Oil Firms

Cecil V. Hagen, Houston, Texas, oil operator and geologist has begun work on a $2,100,000 office building to be completed early next year. Much of the space in the 10-story structure has been leased to oil companies and independent oil operators and consultants. These include Gulf Coast Leaseholds, Inc., Falcon Petroleum Corporation and Talon Petroleum, C. A.

Also in Houston, Michel T. Halbouty, independent operator, is constructing a $300,000 private office building for his staff.

In New York City, The American Oil Company has moved its offices to the newly completed Amoco Building on Fifth Avenue. Amoco will occupy the second through the tenth floors of the 19-story structure.

★ ★ ★

Waterflood Hikes Output

Importance of secondary recovery in Kansas has been made public in one of several recent Interstate Oil Compact Commission publications concerning these operations in various states. In seven Kansas counties producing the major portion of secondary recovery oil, six reported that waterflood oil recovery accounted for more than 65 per cent of the total production. In Greenwood County, almost 4,500,000 bbl of oil were produced by secondary recovery method. Total reported production for Kansas last year was 10,900,000 bbl.

API Production Meetings

District meetings of the American Petroleum Institute's Division of Production will be drawn to a close with the June 6-10 mid-year conference at Denver, Colorado. The Eastern district sessions closed May 13 with nearly 1000 production men attending the Pittsburgh, Pennsylvania meeting.

★ ★ ★

Rocky Mountain Oil Show

Fifty thousand people are expected to attend the first annual Rocky Mountain Oil Show at Casper, Wyoming, June 23-26. Oil companies, suppliers, and service firms have taken space on the 80-acre show grounds.

★ ★ ★

AAODC Safety Clinic

Man-hour and dollar-saving safety program results that have surprised even the safety directors were discussed at the tenth annual Drilling Safety Clinic at Dallas, Texas, May 5-6. The meeting, sponsored by the AAODC, drew nearly 300 to compare notes on efforts to improve already successful and fast-spreading safety program.

"Hank" Kastrop New Drilling and Producing Editor

With this issue J. E. "Hank" Kastrop becomes editor of the Exploration, Drilling, and Producing Edition of *The Petroleum Engineer*. He comes to us from *World Oil* where he has been production editor since 1951, and on the staff of that publication and its predecessor, *Oil Weekly*, for a period of ten years.

"Hank" is a petroleum engineer graduate from Texas University (1941). His oil field career began as a roustabout in West Texas for Humble Oil and Refining Company. Later he was transferred to South Louisiana where, as a roughneck on a drilling rig, he completed his training program, then served as a junior engineer prior to joining the U. S. Navy in 1942. Four years later he joined the editorial staff of *Oil Weekly* as Gulf Coast district editor.

In the course of his editorial career "Hank" has written 70 technical and operating articles on exploration, drilling, and production subjects, has edited more than 500 manuscripts written by others. Pursuit of his duties has taken him into virtually every oil-producing state, as well as Cuba, Venezuela, and Canada.

Kastrop has been active in Gulf Coast industry organizational work with AIME, API, and the Houston Geological Society.

He succeeds Sim H. Crews, who has joined Ernest Cockrell, Jr., independent oil operator of Houston.

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Dual Zone PRODUCTION

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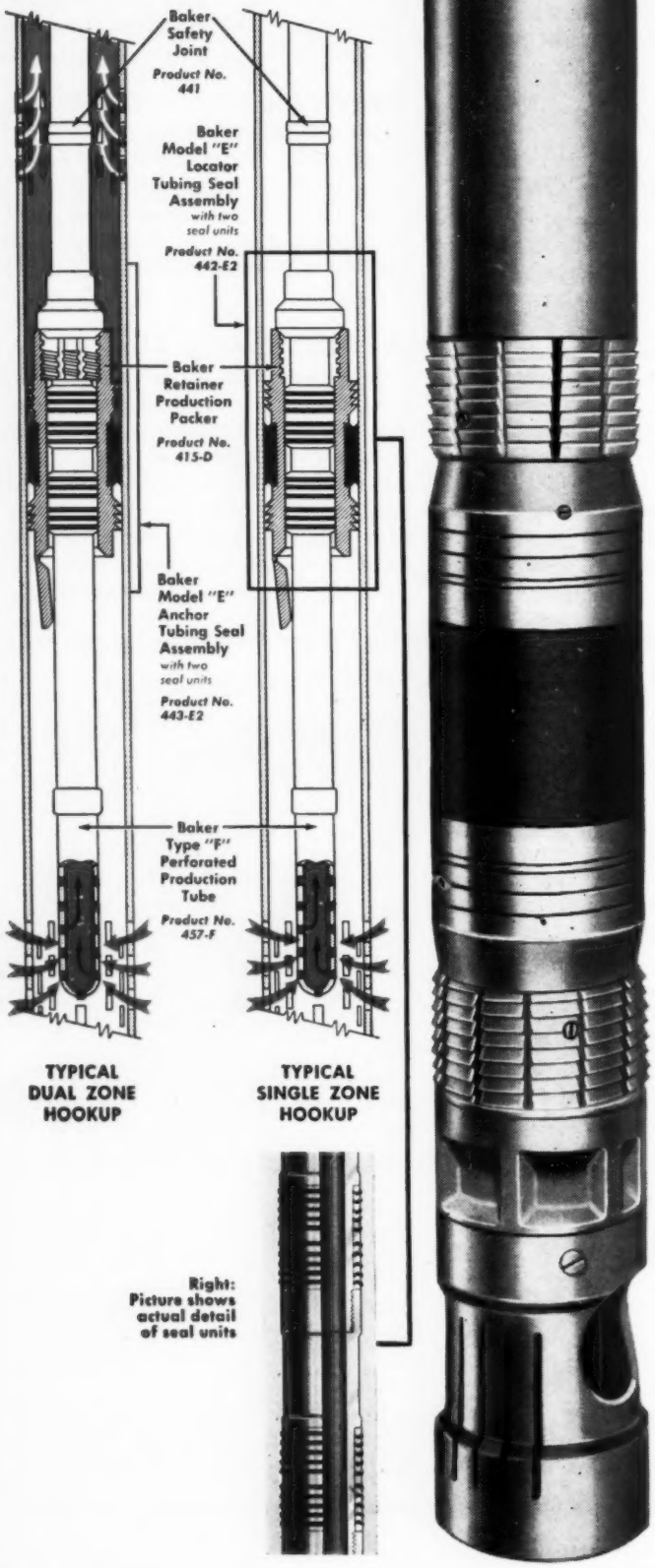
Baker Safety Joint
Product No. 441
Baker Model "E" Locator Tubing Seal Assembly with two seal units
Product No. 442-E2
Baker Retainer Production Packer
Product No. 415-D
Baker Model "E" Anchor Tubing Seal Assembly with two seal units
Product No. 443-E2
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TYPICAL DUAL ZONE HOOKUP
TYPICAL SINGLE ZONE HOOKUP

Right: Picture shows actual detail of seal units

Do you know that with only ONE Baker Retainer Production Packer you can equip your well for *either* SINGLE ZONE or DUAL ZONE production? And that you can accomplish *any* type of completion for *any* method of production to meet *fixed* or *changing* well conditions?

A single Baker Retainer Production Packer will also outperform many specialized tools when used as a TESTING PACKER – SQUEEZE PACKER – GAS LIFT PACKER – PERMANENT COMPLETION PACKER – WATER FLOOD PACKER – GAS INJECTION PACKER – CORROSION CONTROL PACKER – TUBING ANCHOR – ONE-WAY BRIDGE PLUG – PERMANENT BRIDGE PLUG.

Every production man should be familiar with the many operating advantages of this "Universal Type" Packer, which include . . .

WIRE LINE SETTING—The packer can be set with *wire line speed and accuracy,* using the same set-up just used for perforating. The Baker Packer also can be set on drill pipe or tubing.

SETTING UNDER HIGH PRESSURE—By using a lubricator, the Baker Retainer Production Packer can be set under high pressure. From the moment it is set, the self-contained, flapper-type, back-pressure valve closes and isolates pressure below the packer.

TUBING STRING IS ALWAYS "FREE"—That valuable string of tubing—whether 1,000 feet or 16,000 feet in length—can be removed by simply picking up the tubing weight.

EXCESSIVE "SET-DOWN" WEIGHT OR TENSION NOT REQUIRED—Even when squeezing, formation fracturing, or producing at any depth under pressure, a perfect pack-off is maintained independent of excessive set-down weight, or tension.

HOLDS PRESSURE DIFFERENTIALS FROM ABOVE OR BELOW—Two sets of opposed slips, and a resilient packing confined by lead and metallic sealing rings, effect a permanent pack-off that will hold any pressure differential *either from above or below the packer* that is safe for the well equipment.

XUM

Natural Gas Production in Southwestern Virginia

David M. Young

DURING the early nineties of the last century the first test of note in southwestern Virginia was drilled on the Nettle Patch farm of G. W. Gish on Clear Creek, 2 miles south of Ramsey in Wise County, Virginia. Although a detailed record of the well was not kept it is known that the well was drilled to a total depth of 2153 feet with a show of gas reported at 626 ft. Since that time the improperly plugged hole has been known as the "Burning Well" and is still marked by a joint of casing filled with rock and debris by the many visitors through the years.

In 1932 the Penn-Ohio Gas and Oil Company drilled a test in Russell County, Virginia, on property of the Clinchfield Coal Corporation, north of Cleveland, to a total depth of 6002 ft through the Devonian shale. Although shows of gas were encountered, the well was plugged and abandoned without shooting the Devonian shale.

From 1932 to 1934 Benedum Trees was drilling and fishing on the Kaufman well on Guest River near Lipps, in Wise County, Virginia. Through failure to set the production string of casing at the proper depth and while reaming in the attempt to land casing at the proper point, shut-off gas broke through and blew the tools up the hole resulting in a fishing job that lasted more than one year. The hole was finally plugged and abandoned at a total depth of 3760 ft near the base of the Big Lime (Greenbrier).

From 1931 to 1940 the Early Grove gas field of Scott and Washington counties was developed with 7 wells, although two unsuccessful tests were drilled as early as 1910 and 1915. Small and decreasing annual amounts of gas have been marketed locally from this field since 1938. Production is mainly from sandy zones in the Little Valley limestone of Warsaw age.

During the early forties the Virginia Coal and Iron Company drilled three wells on the plunging northeast end of the Powell Valley anticline in Wise County. One was drilled through the horizon of the Oriskany to a total depth of 5348 ft. Another of these wells made a heavy show of gas in the Ravencliff sand at a depth of 1450 ft.

Oil development of significance was secured near the village of Rose Hill in Lee County in 1942 with previous intermittent and unsuccessful drilling since the year 1910. This was the first oil production to be developed in both Virginia and in any area east of the Cumberland-Allegheny Plateaus. The years following 1942 marked fairly intensive development in the area with production of small annual amounts of high grade oil decreasing to less than 10,000 bbl in 1953.

Natural gas in large volume was discovered in Buchanan County in January, 1948 with completion of the United Producing Company 1-V W.M. Ritter. This well made 17,000 Mcf of gas in the Ravencliff sand of upper Mississippian age at a total depth of 2301 ft.

In 1949 gas was discovered in Dickenson County with completion of the Clinchfield Coal Corporation well No. 101. This was drilled through the Berea sand to a total depth of 4551 ft, plugged back and acidized in the Big Lime for an initial openflow of 1632 Mcf.

The discoveries in Buchanan and Dickenson counties resulted in intensive development that continues at the present time and which will be discussed subsequently in greater detail.

In 1949 the deepest test completed in Virginia was drilled by the California Company on a location 2 miles southwest of Blacksburg in Montgomery County. This was drilled with rotary tools to a total depth of 9340 ft in the Moccasin limestone. An estimated 50 Mcf of gas was reported from 7350 to 7480 ft in the Martinsburg formation.

Another noteworthy test was drilled in Wise County in 1949. Located in the vicinity of East Stone Gap where Silurian and Devonian beds are exposed on the crest of the Powell Valley anticline, the well was drilled to a total depth of 4862 ft in Cambrian dolomite. In all probability this well did not penetrate the sole of the Cumberland overthrust block, an important consideration in view of the fact that the Rose Hill oil production to the south was beneath the plane of the thrust block.

In 1950 the United Producing Company completed their 1 J.M. Hoge near

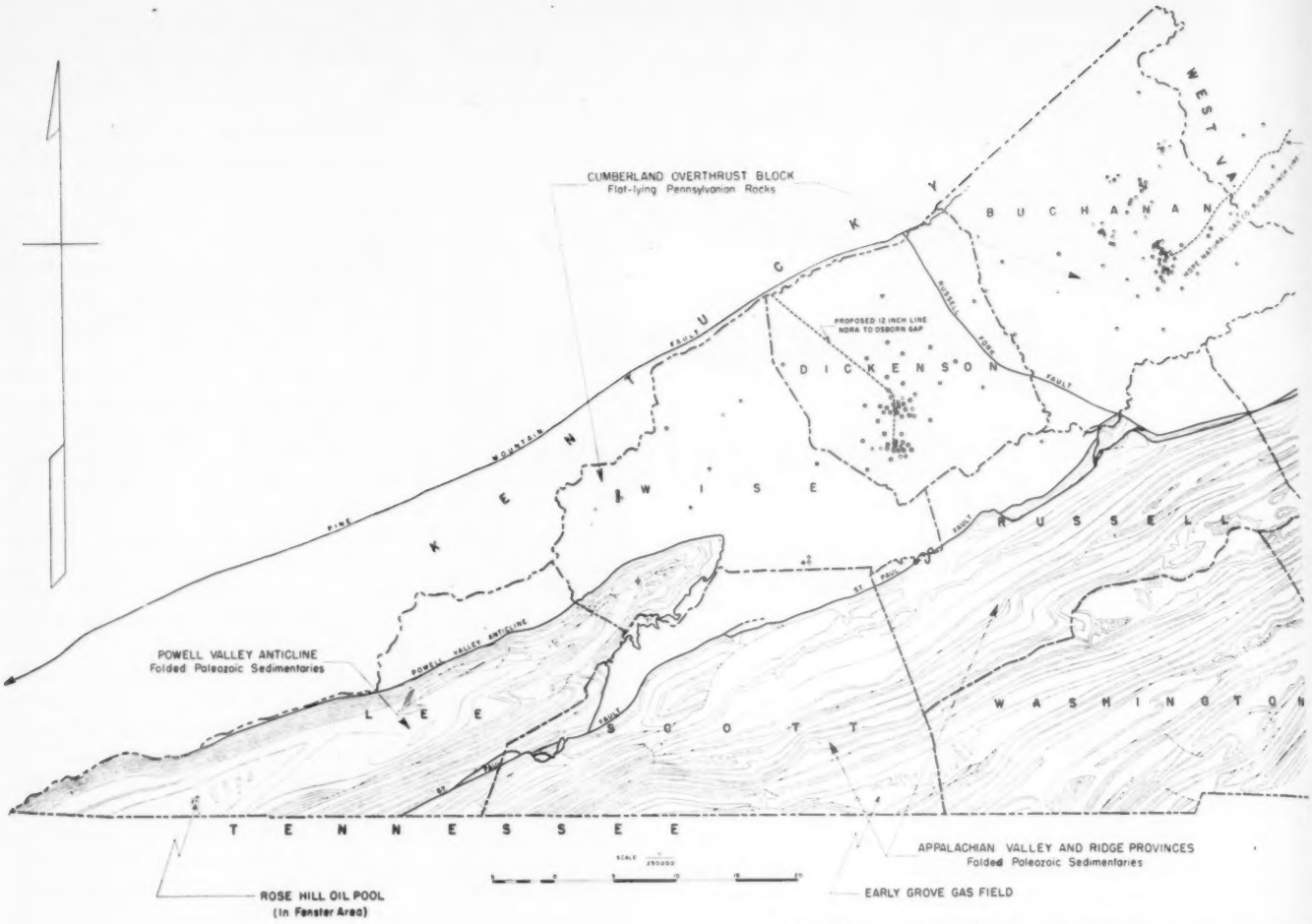
Geology of this Applachians area is complicated—gas production is from a thrust block

EXCLUSIVE

the center of the Burke's Garden area in Tazewell County. The well was plugged and abandoned at a total depth of 5632 ft in the Cambrian.

A final wildcat was drilled in 1951, the New York Mining and Manufacturing Company No. 1 Graham, which was plugged and abandoned at a total depth of 6057 ft through the horizon of the Oriskany. Shows of gas were encountered in the Devonian shale but the well was not shot.

Although not located in southwestern Virginia, Rockingham County in the extreme north-central part of the state in the Valley and Ridge province was the scene of Oriskany sand exploration during 1951 and 1952. The Souder well was deepened and completed as an Oriskany producer in November, 1951. The total depth was


CUMBERLAND OVERTHRUST BLOCK
Flat-lying Pennsylvanian Rocks
PROPOSED 12 INCH LINE
NORA TO OSBORN GAP
POWELL VALLEY ANTICLINE
Folded Paleozoic Sedimentaries
APPALACHIAN VALLEY AND RIDGE PROVINCES
Folded Paleozoic Sedimentaries
ROSE HILL OIL POOL
(In Fenster Area)
EARLY GROVE GAS FIELD
B U C H A N A N
D I C K E N S O N
R U S S E L L
W A S H I N G T O N
T E N N E S S E E

Sketch map of southwestern Virginia showing regional geology and structure, and oil and gas development.

2995 ft, initial openflow 1043 Mcf, and 48 hr rock pressure 1300 psi.

Three additional wells were completed in Rockingham County during 1952, one of which was dry at a total depth of 3098 ft. This well was not shot. The United Fuel Gas Company completed the W.J.B. Moyers No. 1 at a total depth of 3768 ft with the Oriskany sand from 3563 to 3761 ft. Oriskany gas gaged 158 Mcf before the shot and 286 Mcf after. Snee and Eberly completed the S. L. Moyers No. 1 at a total depth of 3077 ft with Oriskany top at 3036 ft. The initial openflow was 9700 Mcf natural with a shut-in pressure of 1310 lb in 25 minutes. No new tests have been started in Rockingham County since the completion of the latter well.

Buchanan County

Since completion of the discovery well by the United Producing Company in 1948 development in Buchanan County has continued to the present time. United Producing has been responsible for the major portion of this development although the Pipe Line Drilling and Construction Company, the Tate Oil and Gas Company, the Clinchfield Coal Corporation, and the United Fuel Gas Company have each completed from 3 to 10 wells.

At the end of 1954, of a total of 74 well completions 43 had a total initial openflow of 144,707 Mcf and 33 were dry. Nine locations were either being drilled, completed, or waiting on rig.

With the exception of a few scattered wells most of the development in Buchanan County has been in the Slate Creek and Knox Creek fields located from 2 to 10 miles northeast of Grundy, the county seat, and the Dismal Creek field about 7 miles southeast. The latter field was the scene of the discovery well.

The greater part of Buchanan County production is from the Ravencliff sand and the Big Lime with smaller amounts developed in the Salt Sand, Maxon, Berea, and Devonian shale. Depths average about 2500 ft for Ravencliff wells, 3500 ft for Maxon, 4000 for the Big Lime, 5000 for Berea wells, and 6000 ft for those drilled through the Devonian shale. Ravencliff initial rock pressures range from 650 to 700 psi and those of Big Lime wells from 1100 to 1400 psi.

During 1952 the Hope Natural Gas Company built a 33-mile 8, 10, and 12-in. extension of their transmission system into Buchanan County which terminated in the Dismal Creek field at a point near the discovery well about 7 miles southeast of Grundy. Deliveries started in November, 1952 and totaled 1,135,545 Mcf by December 31. During 1953 a total of 3,850,934 Mcf was delivered.

The Author

David M. Young is chief geologist in charge of gas department operations for the Clinchfield Coal Corporation, Dante, Virginia. Young received the AB and MS degrees from the University of Kentucky and attended the University of Chicago. For fifteen years he was instructor and assistant professor of geology at the University of Kentucky. From 1945 until 1952 he was employed as geologist by the Kentucky West Virginia Gas Company in charge of the Prestonburg geological office and laboratory in eastern Kentucky. Since 1952 he has directed the gas development program for Clinchfield.

Dickenson County

Shortly after the discovery of commercial gas in Buchanan County the Clinchfield Coal Corporation started development of their large acreage holdings in Dickenson County. The first well, near Nora, Virginia, was completed successfully in the Big Lime with an initial openflow of 1632 Mcf in March, 1949. From that time until the present Clinchfield has continued development drilling and wildcatting in Dickenson, Buchanan, and Wise counties.

At the end of 1954, 58 wells had been completed of which 50 were shut in with a total initial openflow of 80,283 Mcf. Eight wells were plugged and abandoned and one well, not shot, is regarded as incomplete. Six locations were drilling, waiting for completion, or waiting on rig.

Most of Clinchfield's Dickenson County development is in the Nora and Open Fork fields in the south-central portion with scattered wells elsewhere in the county.

Most of the developed gas reserves in Dickenson County are in the Big Lime with smaller amounts in the Salt Sand, Maxon, Berea, and Devonian shale. Depths average about the same as in Buchanan County, Big Lime wells completing at about 4000 ft and Devonian shale wells at 6000 ft. Rock pressures in the Big Lime range from 1000 to 1100 psi, in Maxon wells 980 psi, Berea, 750 psi, and Devonian shale, 900 psi.

During 1951 Clinchfield engaged in a program of seismic exploration over much of their property in Dickenson County. At this time the Nora field had been partially delineated by development drilling and was shot first for control.

Arrangements for sale of Clinchfield's Dickenson County gas have recently been completed with the Kentucky West Virginia Gas Company of the Equitable Gas System. A 12-in. transmission line 15 miles in length is planned from a point near Nora, Virginia to Osborn Gap on Pine Mountain and the Virginia-Kentucky state line. Initial deliveries will be taken from wells in the Nora and Open Fork fields.

Wise County

Although several scattered wildcat wells were drilled in Wise County during the past 60 years it was not until January, 1954 that gas was discovered in significant quantity. At this time the Clinchfield Coal Corporation well No. 155 was completed at a total depth of 4011 ft in the Big Lime and acidized with a resulting initial openflow of 2100 Mcf. The shut-in pressure was 980 psi. This well is located near Stonega, Virginia, 25 miles from Dickenson County production, on a tract of 100,000 acres leased from the Virginia Coal and Iron Company.

Drilling has continued in the area of the discovery well and a southern offset was recently shut in with an initial openflow of 794 Mcf after acidizing with 2000 gal and re-acidizing with 5500 gal.

Prior to discovery of the Stonega pool Clinchfield had drilled 2 Devonian shale wells in Wise County with small initial openflows.

By the end of 1954, a total of 12 wells had been completed in Wise County, including the scattered wildcats drilled prior to discovery of the Stonega pool. Five of those are shut in with a total initial openflow of 4351 Mcf and 7 are plugged and abandoned. Two spudders are currently being operated in the county by the Clinchfield Coal Corporation.

Scott and Washington Counties

Although wells are mostly depleted and drilling activity has ceased, the Early Grove Gas Field of Scott and Washington Counties is interesting for two reasons. First, because of its location in a belt of folded Paleozoic sedimentaries in the Appalachian Valley and Ridge Province and second, because it constituted the first commercial development of natural gas in Virginia.

The first productive well was drilled by the Bristol Natural Gas Corporation in 1931 high on the Early Grove anticline to a total depth of 3613 ft. The initial openflow was 1750 Mcf with a rock pressure of 1500 psi. Only a few wells were drilled by the early forties but in 1938 the gas was marketed in Bristol, Tennessee-Virginia, through a 4-in. pipe line.

The gas in the Early Grove field occurs in calcareous standstones in the Little Valley limestone of Warsaw age. All development was on the Early Grove anticline, the most conspicuous of a series of anticlinal structures in a belt of Mississippian rocks.

Lee County

The Rose Hill Oil Field in Lee County is similar to the Early Grove Gas Field in that production has declined with drilling activity practically at a standstill.

Because of its high-quality oil, however, and because of the unusual geological situation the field is worthy of note in this discussion of southwestern Virginia.

Intermittent drilling was recorded in the area from 1910 to 1942 but it was not until the latter year with the completion of the No. 1 Fugate well that serious attention was attracted to the area. This discovery well had an initial production of 60 bbl per day. By January, 1947, a total of 35 wells had been completed in the field.

In most wells the oil occurs in fractured zones in the Trenton limestone at comparatively shallow depths.

Oil production in the area declined to a total of 7603 bbl in 1953.

Geology and Structure

Southwestern Virginia presents a rather complicated picture in so far as regional geology is concerned, one that has been studied by many authorities on Appalachian stratigraphy and structure.

Part of Buchanan County, most of Dickenson, all of Wise, parts of Scott and Russell, and practically all of Lee County lie within the boundaries of the Cumberland Overthrust Block. This classic structure represents the northwesternmost major movement in the great belt of Appalachian folding and faulting produced by the orogeny that closed the Paleozoic era.

The Cumberland Overthrust Block is approximately 25 miles in width, 125 miles in length and trends northeast-southwest, parallel with Appalachian folding, from the Russell Fork fault in Dickenson and Buchanan counties, Virginia, to the Jacksboro fault in Campbell and Anderson counties, Tennessee. According to authorities on Appalachian structure the block moved from the southeast along a nearly horizontal fault plane some 2 miles on the northeast end and 10 miles on the southwest.

To the northwest the block is terminated by the Pine Mountain fault with Devonian beds resting upon Pennsylvanian. Along the southeast boundary of the block the St. Paul or Hunter's Valley fault brings Cambrian over and against overturned younger Paleozoics.

The block exhibits two conspicuous structures: (1) the Middlesboro Syncline with almost flat-lying Pennsylvanian rocks at the surface and containing important coal reserves in Virginia, Kentucky, and Tennessee; and (2) the Powell Valley anticline plunging to the northeast and exposing along its axis rocks from Cambrian to Pennsylvanian in age.

In Southwestern Lee County, Virginia, the lowermost beds, of the overthrust block have been eroded through in a series of fensters to expose the plane of the overthrust and Silurian and Ordovician beds in the static block beneath. The Rose Hill Oil Field occurs in this area and the discovery well was

drilled within one of these fensters.

Along the axis of the Powell Valley anticline to the northeast successively younger Paleozoic beds are exposed to the point where the structure noses out in the relatively flat-lying Pennsylvanian beds in the coal fields of Wise County.

In all wells that have been drilled through the Devonian shale in Dickenson and Wise counties, a shear zone is penetrated from 40 to 100 ft above the base of the shale or top of the underlying Onondaga or Helderberg limestones. This zone is characterized by metamorphosed bituminous shale that is coal-like in appearance with veinlets of calcite up to 1 in. in thickness. This zone has been regarded as the plane of the Pine Mountain fault or sole of the Cumberland Overthrust.

The interpretation cited above may be open to question when one considers the following facts:

(1) As stated previously, all formations penetrated by wells in Dickenson and Buchanan counties, as well as much older beds, are successively exposed along the axis of the Powell Valley anticline toward the southwest in Wise and Lee counties. The oldest beds are exposed in the fenster area where the Copper Ridge dolomite (Cambro-Ordovician) lies upon beds of Silurian and Ordovician age. Here there can be no question about the position of the thrust plane. Where the Devonian shale outcrops toward the plunging northeast end of the anticline zones of shearing and drag-folding may be seen toward the lower part of the shale section.

(2) When well sections in eastern Kentucky, northwest of Pine Mountain, are compared to those in Dickenson County, Virginia and allowance is made for regional dip and thickening, normal relationships might be inferred.

(3) Clinchfield Coal Corporation well No. 154, located 6 miles northeast of the Russell Fork fault, thus 6 miles beyond the limits of the overthrust block, was drilled through the Devonian shale. A zone of shearing, calcite veining, and gas blowout was penetrated near the base of the shale similar to that encountered in all shale wells in Dickenson County.

(4) Shear zones in the Cumberland Overthrust are not confined to the Devonian shale. Coal seams, notably the Widow Kennedy, exhibit conspicuous evidence of shearing in surface exposures.

Drilling depths in Dickenson County to definitely prove or disprove a fault plane below the shear zone near the base of the Devonian shale would be excessive. However, in areas near the axis of the Powell Valley anticline where older Paleozoics dip beneath Pennslyvanian rocks such depths would be much less.

That portion of southwestern Virginia southeast of the St. Paul fault is characterized by strongly folded and thrust faulted Paleozoic sedimentaries of the Appalachian Valley and Ridge Province. It was on one of the broader folds in this area with Mississippian (Pennington) rocks at the surface where the Early Grove Gas Field was developed.

Surface rocks in Buchanan, Dickenson, and Wise counties are mostly sandstones, conglomerates, siltstones, shales, and coals of the Pennsylvanian Lee, Norton, and Wise formations.

In Dickenson County wells not productive in the Big Lime or shallower formations are drilled on through the Berea sand and Devonian shale to the top of the "Corniferous" (Onondaga or Helderberg). In this interval possible producing horizons range in age from Pennsylvanian to Devonian and in lithology include sandstones, conglomerates, siltstones, limestones, and shale.

Most of the developed reserves in Buchanan County are in the Ravencliff sandstone of upper Mississippian age.

In Dickenson County, the Big Lime (Chester-Ste. Genevieve-St. Louis) is responsible for the bulk of developed reserves. The usual producing horizon is an oolitic facies just above the Hillsdale chert (St. Louis).

Analyses of gas from the different reservoirs in the same vicinity do not exhibit significant variation. Dickenson County gas averages about 95 per cent methane with a Btu of from 1000 to 1050. However, gas from both the Big Lime and Devonian shale in the Stonega pool of Wise County contains less methane and more ethane and propane with a Btu up to 1150. This is of particular interest, not only because the gas quality more nearly resembles that of eastern Kentucky, but because the Stonega area of Wise County is within the Cumberland overthrust, southeast of the Pine Mountain fault where presumably the amount of movement along the sole of the overthrust was greater than in Dickenson County.

Drilling and Completion Methods

Drilling in southwestern Virginia is entirely by cable tools, both standard rigs and spudders being employed. Although completion depths are excessive when compared to eastern Kentucky and parts of West Virginia, daily footage rates are considered good. In one well drilled to a total depth of 6104 ft, a standard rig was on location 186 days and 159 working days. Drilling proceeded on 157 days for a daily average of almost 40 feet.

As is customary elsewhere in the Appalachian Basin where a similar section is drilled, drive pipe is run, usually 13⅜ in, through soil and mantle rock. Ten and three-quarter in. casing is run and cemented to protect coal seams and shut off shallow water.

The amount ranges from 400 to 1400 ft in Dickenson County; 8⅝-in. casing is set below a caving section of red shale and siltstone in the upper Mississippian (Pennington) and amounts average about 2500 ft. The production string of 7-in. casing is set near the top of the Big Lime (Greenbrier) below the "Pencil Cave." Either 2⅜ or 3½-in. tubing is run on completion of a well.

As most of the developed gas reserves in Dickenson County are in the Big Lime, acidization is a routine completion operation. Tubing (3½-in.) is run on an upside down packer and wells treated with from 1000 to 6000 gal of 15 per cent acid. In some cases considerable difficulty is experienced with packer setting because of the fractured character of portions of the Big Lime section. Occurring as it does in an overthrust block one would expect a higher degree of formation fracturing. It is the current practice in Dickenson County to run a caliper survey on completion of a well through the Big Lime in order to find a suitable packer seat. At the same time a temperature survey is usually run to find tops of gas pays.

For those wells drilled through the Devonian shale it is routine procedure to bring them in with heavy shots of 80 per cent gelatinated nitroglycerine. In the nearest field with a long production history for Devonian shale wells (eastern Kentucky), only about 6 per cent of shale wells are natural and the majority are brought in by shooting with gelatine and occasionally other explosives. In most instances more than 100,000 lb of gelatine are used.

In Dickenson and Buchanan counties the Berea sand is the major gas source in some wells. Light shots of gelatine (1000 lb) have been used successfully in Dickenson County and during the past year in Buchanan County sand-fracing has been employed in Berea wells with good results.

Conclusion

In conclusion, gas production in southwestern Virginia presents about the same problems as in eastern Kentucky, West Virginia, and elsewhere in the Appalachian Basin. The stratigraphy and lithology of reservoirs are similar and aside from the fact that much of the area lies within an overthrust block with thicker sections and deeper completion depths the situation is about the same. * * *

SECONDARY RECOVERY of Petroleum in Pennsylvania

William S. Lytle

THE Pennsylvania oil producer started his pioneering in the production of crude oil with the drilling of the world's first commercial oil producer, the Drake Well, in 1859. It was in his oil fields where the first experiments with vacuum, air and gas drive, and waterflooding were made. He continues today, both in the laboratory and in the field, working constantly to discover new methods of recovering additional crude oil from the depleted sands.

Wells in the Pennsylvania oil fields are drilled with cable tools. The central pumping system, which for years operated the producing oil well, is being gradually replaced with individual electric pumps. A further advancement is the back-pressuring and flowing of the producing well. In both air or gas drive and waterflooding, the input well is tubed and the area of the sandface, which is subjected to injection, is controlled with packers.

With the exception of the Second Venango sand of the Conewango Group, Upper Devonian in age, all of the sands under waterflooding are in the Canadaway Group, Upper Devonian age. The sands under air or gas drive are from both of the preceeding groups and one sand, the Berea, is in the Pocono Group of the Mississippian. The use of secondary recovery methods in Pennsylvania has made it economical to operate the depleted oil fields long after they would otherwise have been abandoned.

The estimated natural production curve in Fig. 5 is an estimate of what the Bradford district would have produced if secondary recovery had never been initiated. The broken line in Fig. 1, should be considered in the same light.

Vacuum

John F. Carll, geologist of the Second Geological Survey of Pennsylvania, mentioned in a report published in 1890 that vacuum had been used in the Triumph Oil District of Pennsylvania as early as 1869 to increase the recovery of crude oil from the oil sands. It is customary in the oil and gas industry to use the term "vacuum" to denote a pressure less than atmospheric, but not necessarily meaning absolute vacuum. Later it was discovered that vacuum increased the volume of casinghead gas, as well as the crude oil, and also added to its richness. Within ten years after the drilling of the Drake Well, vacuum was applied by the Pennsylvania oil producer and has been applied continuously somewhere in these oil fields up to the present time. The oil production in general was stimulated only slightly by vacuum, for a comparatively short time, but 4 to 10 gal of gasoline were recovered per 1000 cu ft of gas after compression. The use of vacuum in Pennsylvania was at its height from 1918 to 1925. The total amount of additional oil recovered and the present day production by this method isn't known, but in both cases the amount would be small. About 12 per cent of the present crude oil production in Pennsylvania can be attributed to natural production, some of which is being produced under vacuum. The resultant increase in the viscosity of the oil from the use of vacuum probably left the remaining oil more difficult to recover.

Air and Gas Drive

The first recorded attempt to repressure oil sands with air or gas was made in the early 1900's by Mark B.

EXCLUSIVE

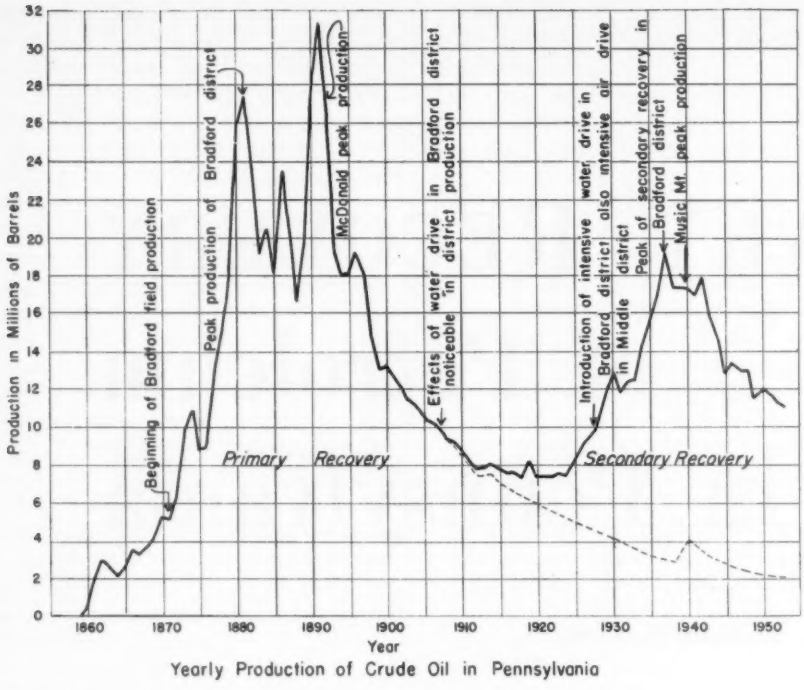

Production in Millions of Barrels
Year
Beginning of Bradford field production
Peak production of Bradford district
McDonald peak production
Effects of water drive in Bradford district noticeable in district production
Introduction of intensive water drive in Bradford district also intensive air drive in Middle district
Peak of secondary recovery in Bradford district
Music Mt. peak production
Primary Recovery
Secondary Recovery
Yearly Production of Crude Oil in Pennsylvania

Fig. 1. Annual production of crude oil in Pennsylvania, showing the influence of secondary recovery and other events upon the production curve

Mitchell at Franklin, Pennsylvania. The method was first successfully used in Pennsylvania in the Hamilton Corners field in 1916 by introducing compressed air into the producing horizon. Since this first experiment, the use of air or gas as a driving medium to increase the oil production continued to increase and was widespread in the Pennsylvania oil fields in the middle 1920's. This method is used extensively today, particularly in the Middle District (Fig. 4). Nine per cent of the state's 1953 production can be attributed to air or gas drive.

In general, 1000 cu ft of air or gas per vertical foot of sand, is injected daily into each input well under pressures ranging from 50 to 400 psi. As symmetrical a well-spacing pattern as is possible to obtain with the old oil wells and new pressure wells is followed. For intensive development, the uniform "seven-spot" pattern is used. This nomenclature is not quite correct and the pattern is more correctly known as the "reverse seven-spot" for each producing well is actually affected by three inputs. The spacing in this pattern is 150 to 250 ft between inputs and producers with a ratio of about 2 producers to 1 input. From 10 to more than 100 bbl of oil per acre-foot can be recovered by air or gas drive and indications are that only oil in excess of 150 bbl per acre-foot is recoverable by this mechanical method. During the life of a project, between 6 and 22 Mcf of air or gas is injected per barrel of oil produced.

Air or gas drive is used extensively in the following fields (Fig. 2): Music Mountain, Cooper, Tidioute, Colorado-Goodwill Hill-Grand Valley, Balltown-Truemans, Watson-Duhring, Church Run, Pleasantville, Shamburg, Petroleum Center-Pioneer, Oil City-Rouseville, Foster-Reno, Cranberry-Rockland Bullion-Clintonville, Volant and Carson and less extensively in the Gartland, Kinzua, Walnut Bend, Clarion-Miola, McDonald, and Washington-Taylorstown fields.

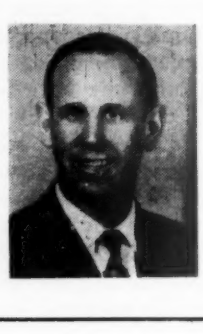
The sands (Fig. 3) under air or gas drive are the Berea, First, Lytle, Red Valley, Second, Knox Third, Third Stray, Gray, Gordon, Third, Fourth, Fifth, Balltown, Cooper, and Sliverville.

The McDonald and Washington-Taylorstown fields each has one gas drive project in operation. Gas drives, which cover but a small part of these two fields, are not applied intensively but have yielded outstanding increases in oil production. These two fields and a number of other fields in Pennsylvania should yield considerably more oil economically when air or gas drive is intensively applied. Also, some sands which haven't come under air or gas drive should respond favorably under an intense application of this method. The peak year in production by air or gas drive was 1929. At present there are about 2185 air or gas input wells affecting 7740 producing oil wells in Pennsylvania's air or gas drive projects.

Water Flooding

In a publication of the Second Geological Survey of Pennsylvania in 1880, the author, John F. Carll, called attention to the possibilities of systematically employing waterflooding to increase the recovery of oil. Waterflooding was probably secretly practiced in the early 90's in Pennsylvania, but didn't come into extensive use until about 1920 and was legalized for certain sands in Pennsylvania in 1921 by an act of the state legislature. Artificial waterflooding has been developed into the outstanding method of producing oil in Pennsylvania. Seventy-nine per cent of the state's 1953 production can be attributed to waterflooding.

In general an average of 8 to 9 bbl of water is required to produce a barrel of oil, although for some projects an average of up to 25 bbl of water may be used when computing for the entire life of the flood. The flood water, which is introduced under pressure at the top of the intake well, comes primarily from shallow fresh water wells, but also from surface water and springs. Until recently the water was usually obtained through an open system or air-free system, treated and filtered before injection. During the last two years more operators have changed over to the closed system, where the floodwater is obtained from shallow fresh water wells and injected without treatment or filtration. The pressures applied in the intake wells at the sand face are as high as 1800 to 2000 psi. The producing well is generally located in the center of a square and is surrounded by 4 intake wells at the corners of the square. This pattern is known as the "five-spot."



The Author

William S. Lytle was appointed director of the Pennsylvania Topographic and Geologic Survey's field office in Butler in 1947. Since then he has worked in the Pennsylvania oil and gas fields collecting data for geological and engineering reports. He authored the Survey publication *Crude Oil Reserves of Pennsylvania*. His work on the survey, begun in 1940, was interrupted by a 5-year tour of duty in the U. S. Corps of Engineers.

Lytle was graduated from the Pennsylvania State University with a BS in petroleum and natural gas engineering.

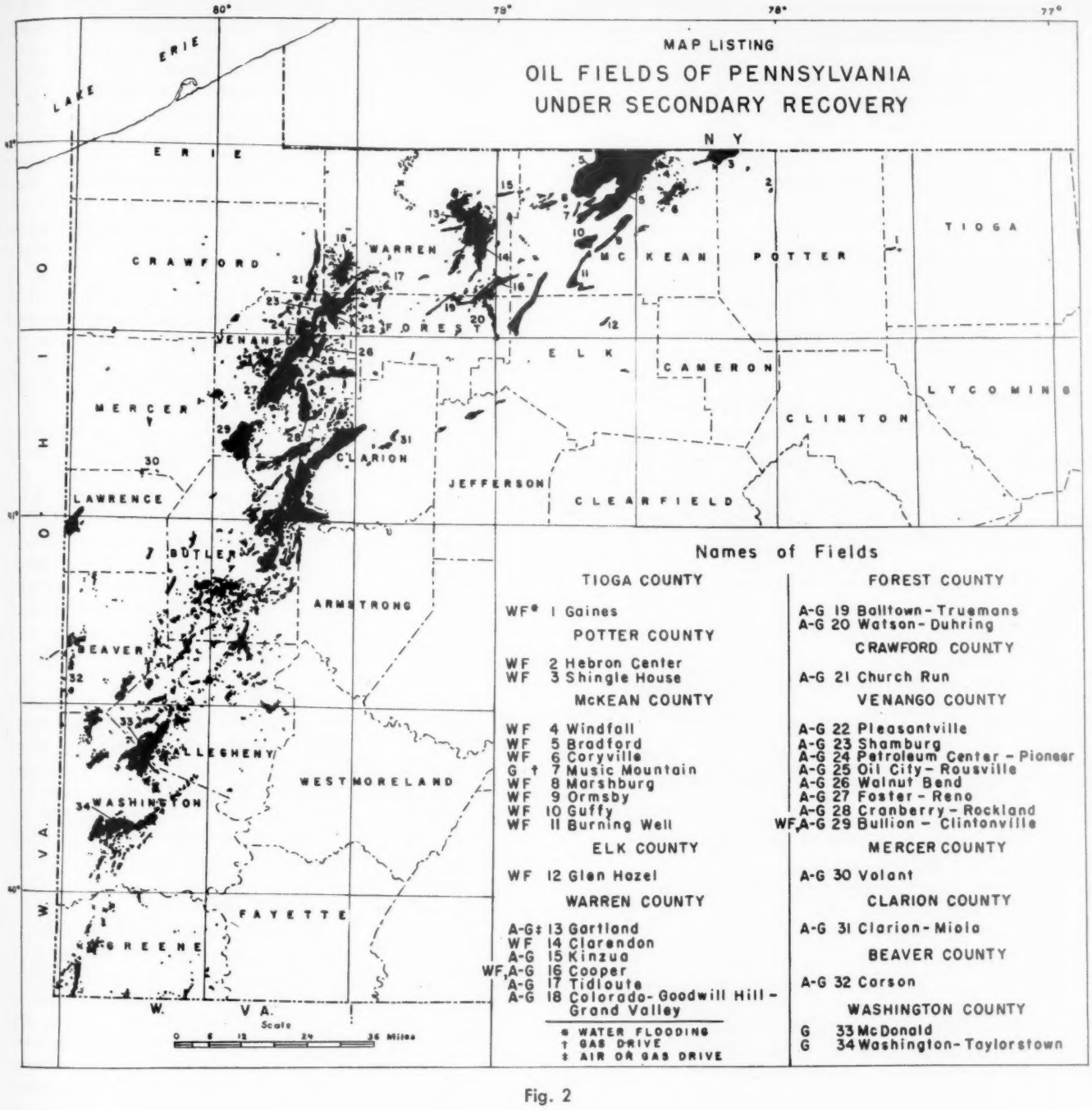


Fig. 2

The distance between intake and producing wells varies from 225 to 250 ft. Until recently most producing wells were generally pumped, but the method of back-pressuring and flowing of the oil is becoming more common. Some holdings in the Bradford pool have produced over 10,000 bbl per acre.

Most of the economically successful waterfloods in Pennsylvania are located in the northern district. An economical flood is located in the middle district in the Bullion-Clintonville field where the Second sand is being flooded. Except for this flood and a recent waterflood experiment which shows signs of success, other floods haven't been successful in this district. The Bradford pool located in the northern district contributes the major part of the oil obtained by waterflooding. Other successful waterflooding on a fairly extensive scale is being conducted in the Clarendon, Guffy, Burning Well, and Shingle House pools and on a smaller scale in the Hebron Center, Corrysville, Glenhazel, Marshburg, Ormsby, Kings Run, and Windfall pools. Waterflooding in the Gaines and Cooper fields hasn't been very successful. The Clarendon pool obtains its oil from the Clarendon sand while oil recovery from the other pools is obtained from the Bradford Third sand or a sand at approximately the same geological horizon. Fig. 5 is a graphic illustration of the oil production obtained from the Bradford district. This district, consisting of about 100,000 acres, is in the northern crude oil producing district and includes the production of all of the Bradford (14 per cent lies in New York), Guffey, and Burning Well pools. Over 90 per cent of the production from the Bradford district comes from the Bradford pool.

The peak year for primary production in the Bradford distict was 1881 when 22,945,069 bbl of cude oil were produced, while the peak year in production by waterflooding was 1937 when the production for the district amounted to 16,690,688 bbl. In Pennsylvania's waterflooding operations to-

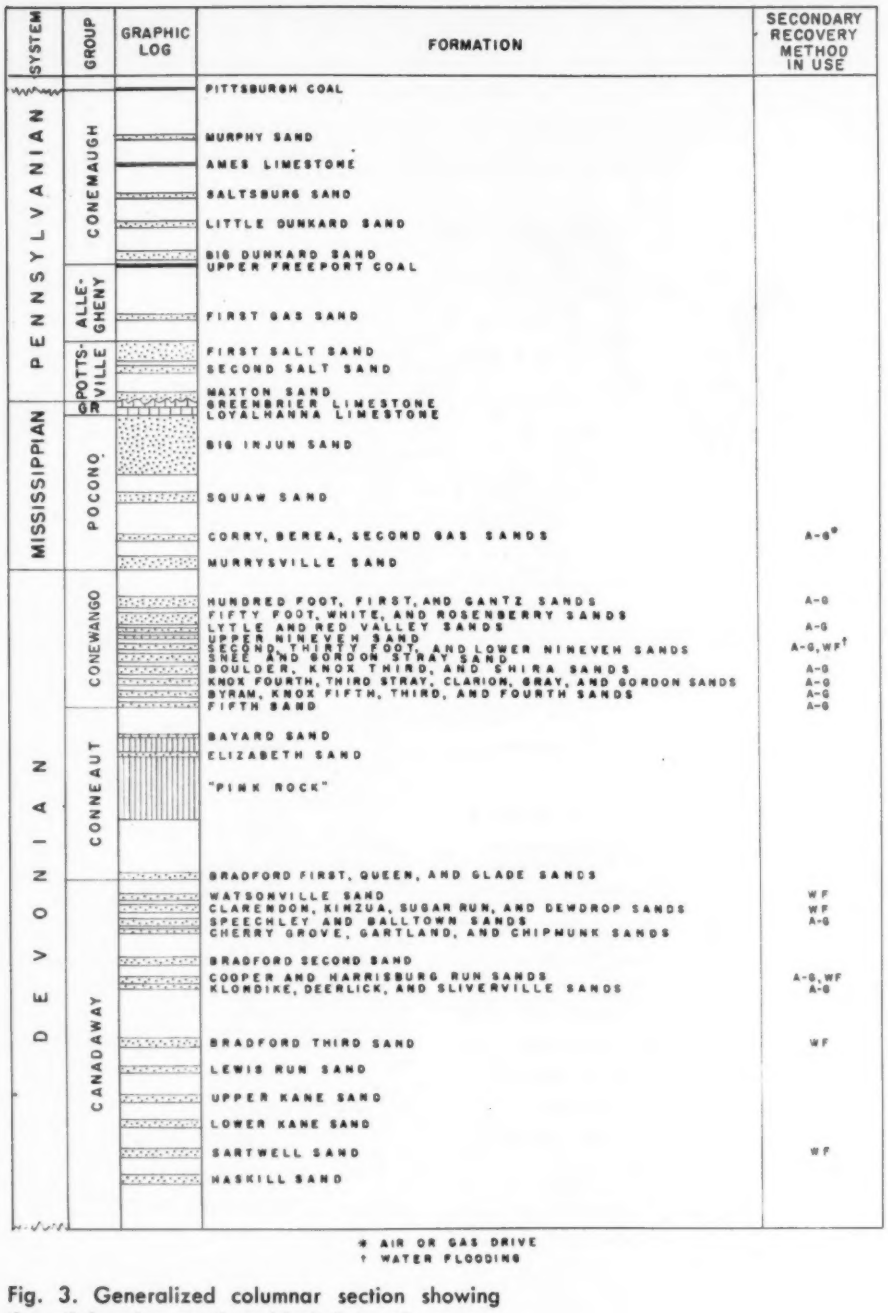


Fig. 3. Generalized columnar section showing the oil bearing sands subjected to air or gas drive or water flooding in western Pennsylvania

day there are about 25,362 water input wells affecing 23,545 producing wells.

Reserves

In Pennsylvania as of January 1, 1954, it is estimated conservatively that there were 2,651,108,000 bbl of oil remaining in the known reservoirs and that a cumulative total of 1,180,310,000 bbl of oil had been produced including 10,000,000 bbl that ran to waste in the early boom days. Therefore, a conservative estimate as to the original crude oil content of the known oil reservoirs in Pennsylvania, is about 3,831,418,000 bbl. Of the oil remaining as of January 1, 1954, it is estimated that 110,892,000 bbl are proved recoverable by primary plus secondary methods. Most of this recoverable reserve will be produced by the northern district. In making this estimate of proved reserves, no value was given to secondary recovery possibilities in fields that are not now using these methods. The estimate is a conservative one and will probably be revised upwards in the next few years.

The peak year in production by primary methods was 1891 (Fig. 1), when a total of 31,424,000 bbl was produced. This peak was largely due to the flush production of the McDonald field. Following a period of declining production, a secondary peak was attained in 1937, when 19,990,000 bbl of crude oil was produced largely by secondary methods. In 1953 the annual production had declined to 10,930,799 bbl.

The Bradford district is currently producing about 45 per cent of all the Pennsylvania-grade crude oil. About 556,096,000 bbl, or 5500 bbl per acre, had been produced by January 1, 1954, in this district, of which 257,498,000 bbl can be attributed to natural production and 298,608,000 bbl to flood production. The total recovery in Pennsylvania by secondary methods at the end of 1953 was 317,208,000 bbl, 300,208,000 bbl were produced by waterflooding and 17,000,000 bbl by air or gas drive. Subtracting this total secondary recovery figure from the total oil produced at the end of the same period leaves 863,102,000 bbl total natural production.

The northern district is producing 85 per cent of the present Pennsylvania oil production, while the middle district is producing 11 per cent and the southern district 4 per cent. Most of the oil fields in the northern district are under secondary recovery development. A number of fields in the middle and southern districts not yet producing under secondary recovery methods should respond favorably to air or gas drive.

Of the Pennsylvania oil industry's 103,886 wells, 25,362 are water input wells affecting 23,545 producing oil wells; 2185 are air or gas input wells affecting 7740 producing oil wells and the remaining wells, over 45,000 are oil producers, either natural or under vacuum.

Technical Advances

Probably more additional oil is being produced from the Pennsylvania oil sands due to the combined improvement of oil techniques, rather than to any one new technique. Some of the factors which have increased the total amount of oil produced by waterflooding are: Improvement of drilling practices, cleaning out practices, selective shooting and drillers' logs; better interpretation of electric, gamma ray, temperature logs, etc., drill cutting descriptions and input and output information; better well spacing for maximum oil recovery; better well location procedures, equipment and pumping schedules; increased knowledge of water treatment; the use of electric jacks; and, one of the most important, the education of the pumper and the roustabout in proper secondary recovery procedures.

The following can be said of the new techniques in waterflooding procedure in Pennsylvania. Selective plugging with a soft wax emulsion, a hard oil-insoluble resin emulsion, and various plugging agents in an oil mixture have

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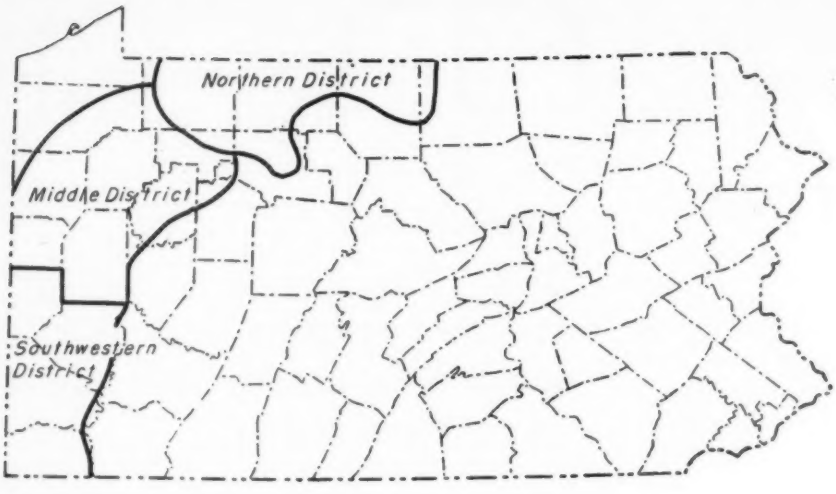

Fig. 4. Crude oil producing districts in Pennsylvania

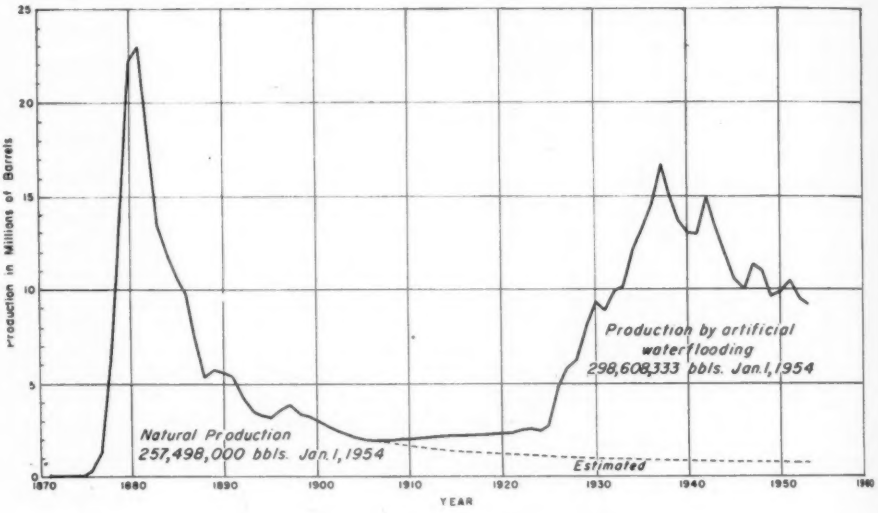

Fig. 5. Crude oil production curve of the Bradford district, Pennsylvania and New York. (Music Mountain field excluded)

all been used successfully to some extent. Selective shooting is in wide application. An experimental pilot flood using the Orco process (carbon dioxide in flood water), has been tried. All producers obtaining floodwater through an open system or air-free system treat and filter it, but more operators are changing to a closed system with no treatment or filtration. A pilot flood where the inputs were hydrafracted is now in operation—hydrafraction increasing the water input. Increased water input has had marked success when the input well is treated with hydrofluoric acid and in some instances hydrochloric acid, although acidizing is not yet in common use. The trend is toward back-pressuring and flowing rather than pumping. Inter-drilling and delayed drilling is used to some extent. Field experiments have been made using wetting agents, smoke plugging, hot water injection and gas slugging. The use of bacteria to release oil from the sand has been used experimentally in the laboratory. One new technique of note, which probably will increase the total oil produced in a new development, is the injection into a water input well of about 400 M to 600 M cf of gas, depending on the individual well, before starting the flood. The amount of increased oil production is rather hard to determine in this technique, but this practice is becoming common in water-flooding. In the realm of speculation is the use of high viscosity water for increased oil recovery in waterflooding.

Many of the above improvements and new techniques apply to air or gas drive. Probably two of the most important field experiments in this method of secondary recovery are: (1) heating the sandface of the producer, which removes water blocks and paraffin, in some instances increasing the production fourfold; (2) back-pressuring and flowing the producer rather than pumping. Both of these methods have been profitable in the two field experiments, but as yet they are not in common use. Pressure cycling, the build up and release of gas pressure on the sandface in the producing well, has increased production on a number of properties. It is hoped that the use of surface active chemicals to remove water blocks from damaged producing wells will be successful. Probably the most important technique is the use of the "reverse seven-spot" for intensive air or gas drive.

Summary

Since the completion of the world's first commercial oil well in Venango County, Pennsylvania in 1859, almost 4 Million barrels of crude oil have been discovered in this state. Over 25 per cent of this oil has been recovered to date and 27 per cent of the recovered oil has been recovered by secondary methods. Most of the proved recoverable reserves of 110,892,000 bbl will be recovered by secondary methods. With the development of new techniques and a profitable price structure in the Pennsylvania oil industry, it should be possible to recover over 500,000,000 bbl in addition to the above proved recoverable reserve.

Acknowledgment

The author is grateful for the help of several engineers who contributed information used in the preparation of this article. Miss Lillian Heeren of the Survey staff, did the drafting of the illustrations.

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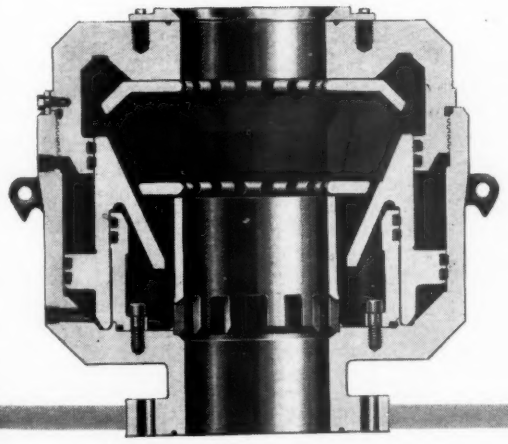

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FIG. 1. Illinois Geological Survey mobile field intensity equipment used for measuring radio wave signal strength.

REPORT ON

PETROLEUM EXPLORATION WITH RADIO WAVES

Fred W. Kelly, Jr.

Part I—Prospecting for Structure

ALTHOUGH little is known by many geologists about the use of radio as a geologist's tool, this method of exploration is not new. As early as 1932 work was started in Texas to try this method. Since the early trials, much research and application has been done by institutions and organizations in the United States. The purpose of this research was to determine the relation between geologic conditions and radio-wave transmission and to evaluate the variations in radio-signal intensity or some other measurable value of radio waves for application to geological and geophysical problems.

Field Instrumentation

The equipment to be used with this method must be sufficiently portable and at the same time capable of accurately measuring and recording changing signal intensity. Also, any interruptions or breaks in a radio beam must be detected and recorded.

The equipment used by various workers is generally similar and consists of the following components:

1. A sensitive radio receiver of portable design.
2. An antenna (loop or vertical).
3. A graphic recorder providing a continuous record on paper.
4. Speedometer linkage to the recorder geared to give a continuous record corresponding to mileage covered.

A variety of field instrumentation ranging from metering equipment inserted into conventional automobile radios or into portable communication receivers to precise equipment for measuring field intensity has been used. The arrangement mentioned last is preferred by most.

The Illinios State Geological Survey[1] has been investigating the possibilities of the geologic aspects of radio wave transmission since 1945. After much testing, they finally selected a combination of a commercial precision field-intensity meter, a 10-milliampere graphic recorder, and a speedometer drive arranged so that records can be made against distance or time.

Records against distance are preferable, with 2½ in. of continuous record equal to one mile of covered road being commonly employed.

While there is a problem of availability of roads, most work has been done with equipment installed in automobiles. The Norman L. Stevens Company[2] of Bangor, Michigan, however, has designed equipment that can be used in airplanes and automobiles, or carried on the backs of the operators. With this equipment a continuous record can be made in an airplane when traveling at 120 to 160 mph. Automobile records can be made at speeds of about 50 mph.

The airplane surveys pick up only the major subsurface anomalies. These findings can be relayed to an automobile and finally to units packed by men in order to obtain detailed information. With most organizations, however, information from automobile units is sufficient.

Records are obtained using calibrated shielded-loop antennas and also non-directional vertical antennas. Precision measurements of signal strength in microvolts per meter are possible with the loop antenna, or relative signal strength only may be recorded.

Depth Penetration of Radio Waves

Until very recently, it was the conventional belief among geophysicists and radio engineers that radio waves will not penetrate more than a few hundred feet into the earth. Now, however, many believe that under proper

*This article prepared for *The Petroleum Engineer* is based on a paper written at the University of Tulsa as a course term paper. It won first prize in the first technical paper contest for students in the engineering college. The contest, held in January 1954, was sponsored by the TU College of Petroleum Sciences and Engineering, and Tulsa chapters of American Institute of Chemical Engineers, American Institute of Mechanical Engineers, and Instrument Society of America.

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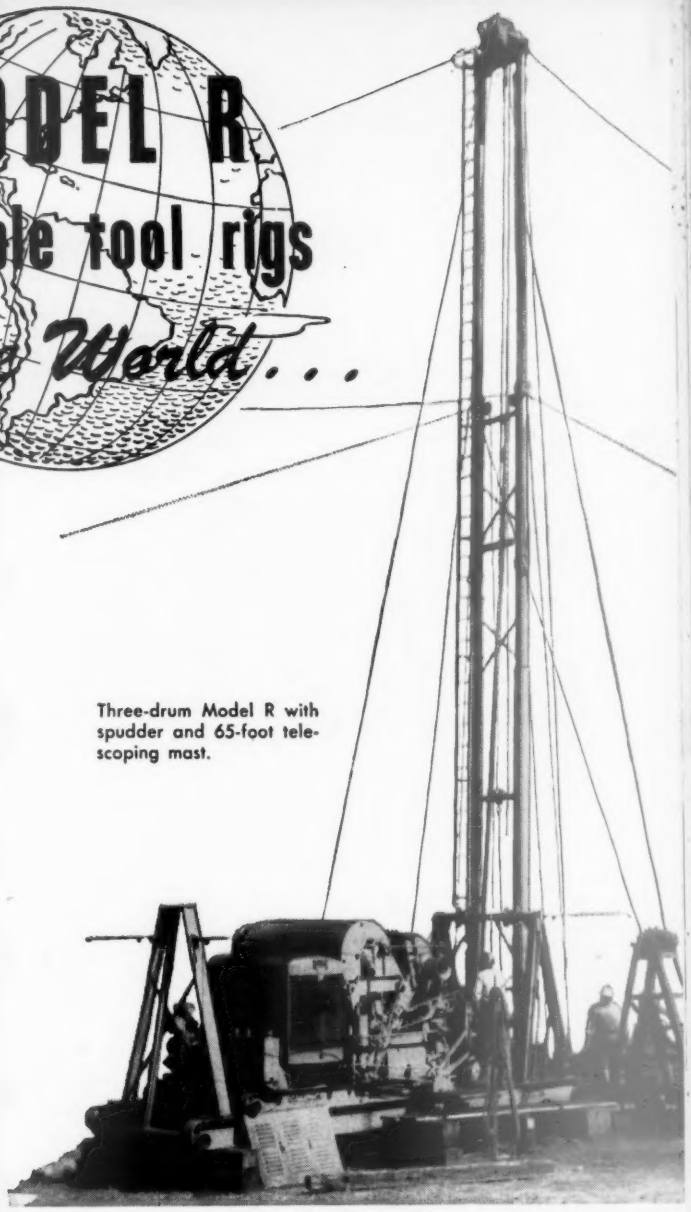
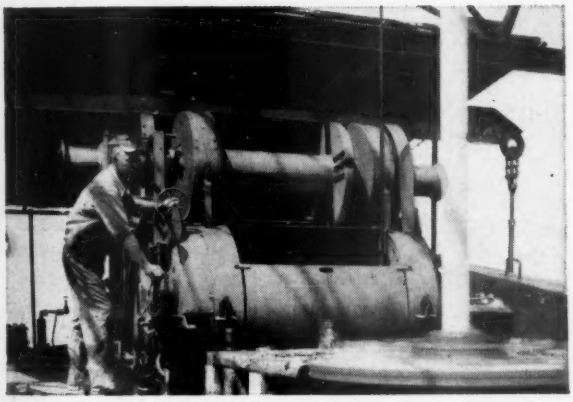


Three-drum Model R with spudder and 65-foot telescoping mast.



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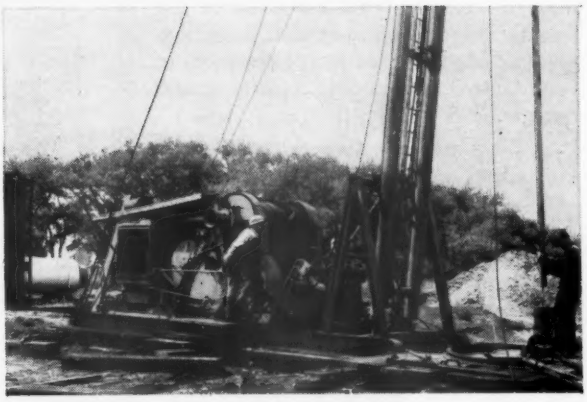
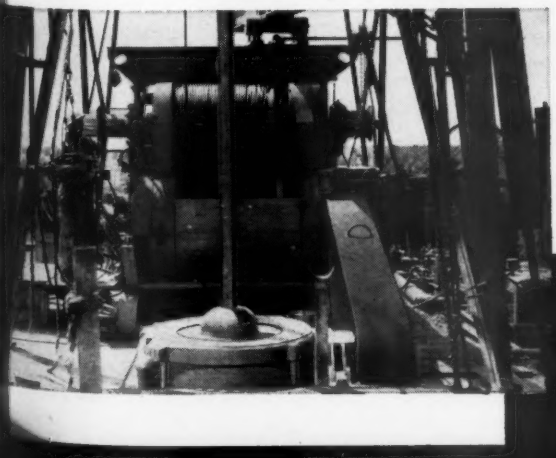


Double drum with spudder and 65-foot telescoping mast on drilling-in job.



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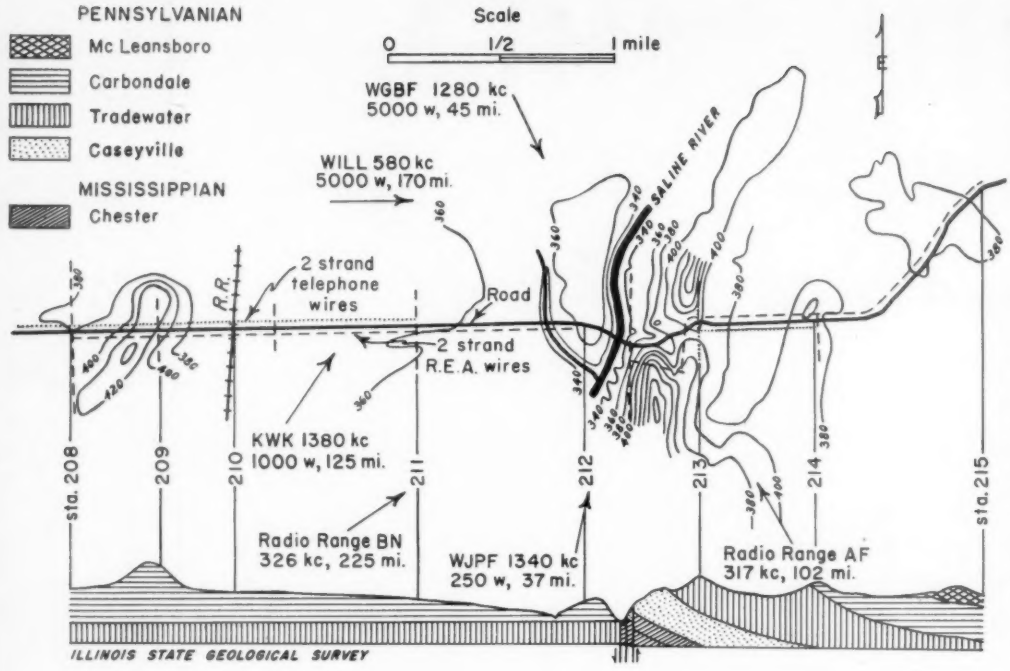


FIG. 2. Field-conditions map and geological cross-section in area of selected traverse along Illinois Highway No. 1 in Gallatin County. The topography, the recognized possible field hazards such as power and telephone lines, bridges, bodies of water, railroad tracks, and the critical information on radio transmitters used for surveys of the area are shown on the sketch map. The geological cross-section at the bottom of the figure shows the structure and stratigraphy along the traverse line, crossing the Shawneetown fault. (Surficial materials not shown.)

FIG. 3. One record of signal strength along route shown in Fig. 2. Loss in field intensity in passing from younger Pennsylvanian strata (on which antenna of station WJPF is located at Herrin, Illinois) north of the Shawneetown fault to older strata to the south of the fault is shown between stations 212 and 213 (Effects of the bridge, overhead wires (oh), stream, and railroad tracks are also recorded.

conditions radio waves at broadcast frequencies (550 to 1600 kc) and lower (radio range, military, etc.) penetrate the earth's crust for considerable distances.

Many experiments in radio propagation through rock have been made to test the efficiency of radio communication in mines and caves.

Wadley[3] conducted experiments on the transmission of radio waves in deep mines in South Africa. His experiments showed that transmission took place through the rock, and dependable transmission was obtained up to distances of 2500 ft.

Volker Fritsch[4] investigated the conditions of radio propagation in mines in the potassium salt deposits in Germany. In one instance reception was obtained between two mines 14 kilometers (about 8.7 miles) apart.

The Author

Fred W. Kelly, Jr., was graduated in January, 1954, from the University of Tulsa with the degree of bachelor of geology. He joined The Ohio Oil Company as a geologist after graduation and presently is located at Ardmore, Oklahoma. During summer vacations, while attending the University of Tulsa, he was employed as a geologist, aerial photograph interpreter, and topographer by various oil and pipe line companies. He has been an amateur radio operator for six years, and presently holds an amateur class A license and a commercial second class radio telephone operator license.

In most cases, experiments have demonstrated that radio waves do penetrate the earth's crust for some distance.

Character of Electrical Indications

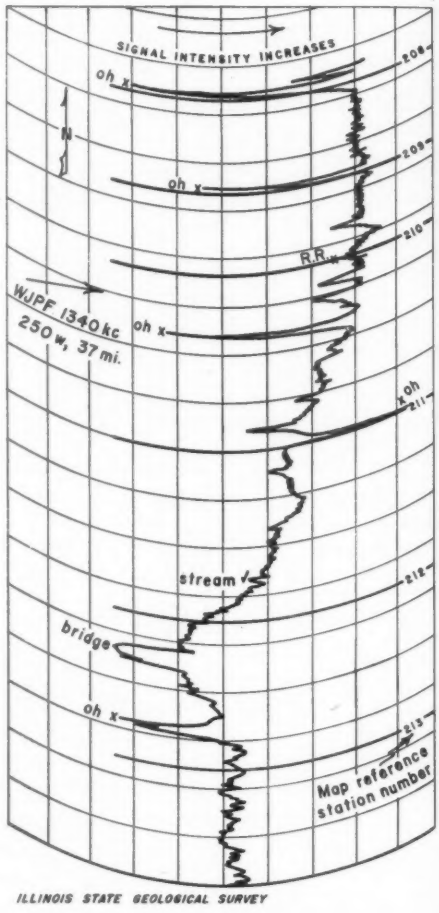
Subsurface geologic features, under proper conditions, cause anomalous signal intensities to exist at the surface above. These anomalies may be detected by using radio equipment, thus locating geologic features otherwise concealed in the subsurface. Once located, these geologic features may then be evaluated as to possible oil accumulations.

The origin of intensity anomalies associated with geologic features has been interpreted as due to the lithologic and/or chemical dicontinuities of the strata which result in electrical or magnetic discontinuities such as changes in conductivity, dielectric constant and magnetic permeability.

Others express their ideas for the variations as secondary fields interfering with the primary fields, reflection and refraction of the primary field, and consideration of the action of the law of critical angles on a field after it once enters any substratum.

Theoretical considerations of field-intensity behavior in earth materials have not been thoroughly treated as of yet; primary attention has been given to signal-strength behavior as measured in the field and to the factors controlling this behavior.

The Illinois State Geological Survey[1] reports, "Best reception appears to take place where receiving and transmitting antennae are on or close to the same rock strata. If the physical dimensions of a rock stratum with high electrical resistivity are compatible with those of the wave lengths of the signals used,



and if the stratum is bounded above and below by shales or other beds with low electrical resistivity, radio fields appear to be carried by the bedrock stratum, in effect, as a wave guide."

If this wave-guide concept of radio transmission is confirmed by further geophysical investigation, many important practical applications may be put into use. By energizing selected strata the areal extent and structure of geo-

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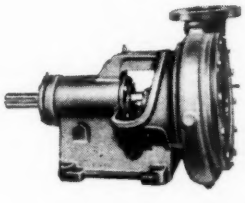

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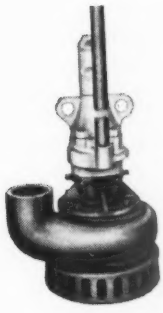

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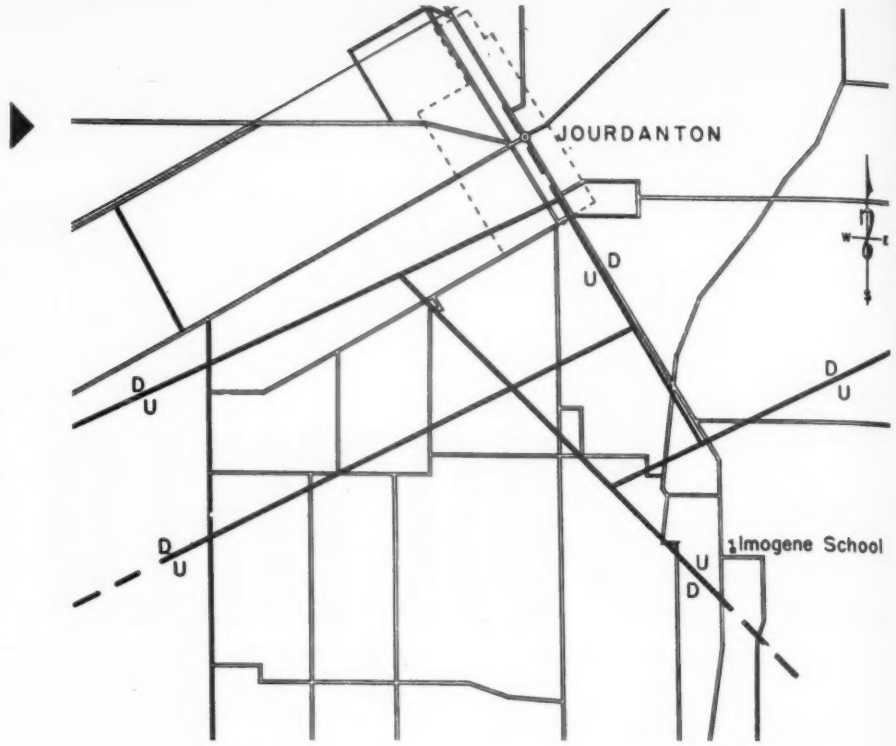

FIG. 4. Network of intersecting faults as determined by a series of radio-intensity surveys along traversable roads in the area around Jourdantown, Texas. The survey not only determines the trend of the faults, but indicates the up-and-down throws of the individual faults enabling the spotting of wells on a favorable prospect.

logic formations might be identified. Detection of metallic ore deposits and lithologic changes, such as reefs in limestone, may be possible in the future by radio methods.

Radio waves either penetrate to greater depths than some theories show possible, or the anomalies which are determined are caused by differences in physical properties brought about by the presence of oil or gas at depths, or by structure, or both.

Application of Method

Only continuous signal-intensity records made in areas where no "sky wave" signals are observed during the daylight hours are used to outline geological conditions in the subsurface. This is to eliminate error and confusion due to reflected waves from the ionosphere or troposphere.

Using these records, iso-intensity contour maps may be constructed. These contour maps will locate structures such as: Anticlines, synclines, noses, and normal dips. The surface and near-surface traces, and sometimes other features of faults, can be delineated very accurately.

At the present time, no data can be derived from radio-transmission curves, recorded by the previously discussed equipment, which indicate the depth of any recorded structural condition. Of major significance is the fact that hundreds of traverses over known geologic structures show that these records will continually duplicate themselves when rerun. In addition, it has been shown that the records show both gradual and sudden changes in intensity.

The possibility of radio-intensity prospecting for ore bodies is indicated by the interpretation of some workers that concentrations of pyrite, marcasite, and associated zinc and lead ores at shallow depths cause prominent signal anomalies in some localities.

In interpreting radio-intensity records for geologic information, the interpreter must be able to recognize the effects of wires, streams, bridges, railroad tracks, metal fences, topography, vegetation, etc., all of which are usually encountered along the traverses.

As examples of the applications of this method, consider the following illustrations. Fig. 1, 2, and 3 are taken from an Illinois State Geological Survery circular.[1] Fig. 4 and 5 illustrate maps which may be constructed from radio surveys.[10]

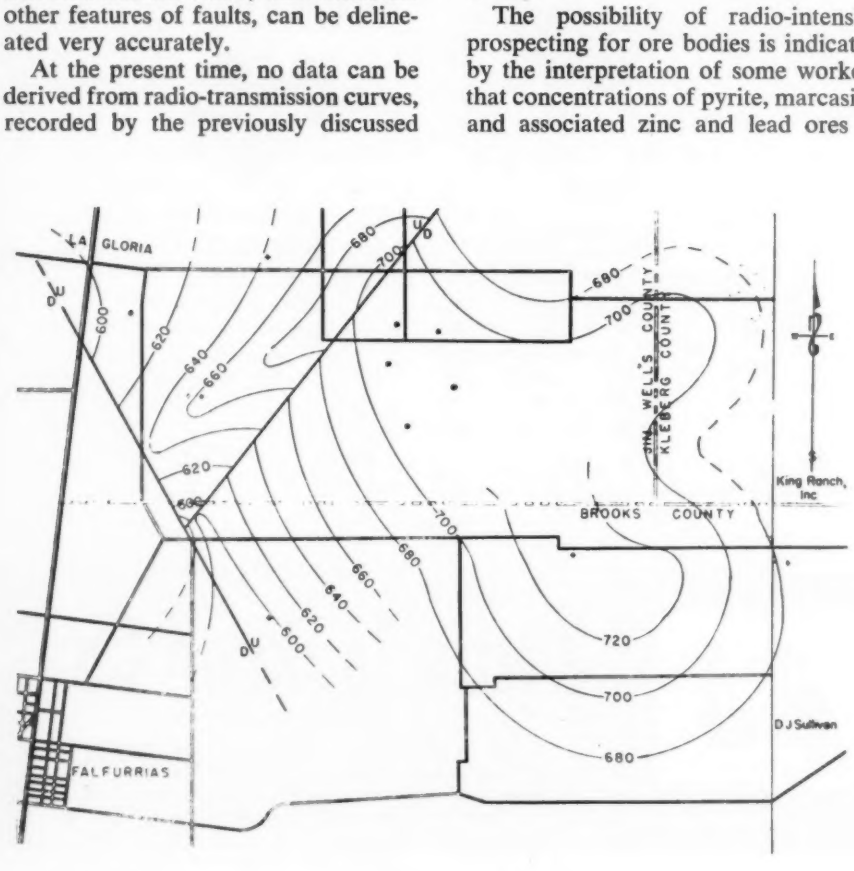

FIG. 5. Contours on iso-intensities of broadcast fields as developed for area northwest of Falfurrias, Texas, with location of two faults. Survey was conducted on a network of intersecting roads not shown on this map.

Conclusion

Prospecting for geologic structure with radio waves, although in the experimental stage of development, has several distinct advantages. Continuous records, made without stopping (as must be done with much geophysical equipment) result in high-speed operation at low cost.

This method should be used with other geologic and geophysical methods which are applicable in the area involved. For instance, faults, which are not always picked up by seismic methods, could possibly be picked up with radio methods.

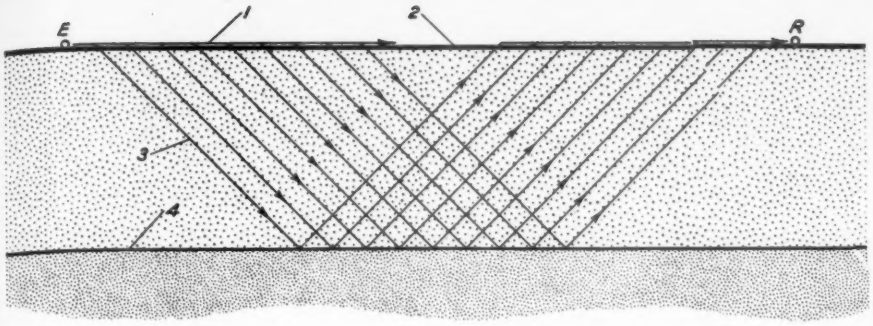

FIG. 6. Wave paths utilized by the radoil method.

Part II—Direct Location of Oil Accumulations

THE thought of directly locating oil fields by electrical means is not new. The electrical properties of petroleum differ markedly from those materials that enclose it in nature, and many workers have attempted to develop electrical instruments that can make use of these differences in directly locating oil.

The necessity of concentrated paths of flowing electrical energy to probe the subsurface seems to eliminate direct current and low-frequency alternating current. Easily focused high frequency electromagnetic waves seem to be the answer. Reflection of these high frequency waves at the surface, absorption a comparatively short distance in the earth, and necessity of seemingly elaborate antenna systems are the problems which have slowed development of this method of oil detection.

A method, which apparently overcomes these difficulties and which has been field tested with satisfactory results, has been developed and patented by William M. Barret, Inc.[5] of Shreveport, Louisiana, and is known as Radoil.

Barret engineers found that geologic strata are characterized, as are most materials in nature, by varying degrees of selective absorption. This means that rock strata will transmit electromagnetic waves of a particular frequency band with far less absorption than other frequencies. Frequencies they arrived at, however, were ill adapted to the transmission past the air-earth boundary, or for concentrating the wave energy along controlled paths; each is a fundamental requirement. It became necessary for them to develop a basically new mechanism to solve the problems.

The new mechanism, which William M. Barret, Inc. developed and is now using, will be covered in what follows. The rest of this article is based on material and illustrations from the Radoil method of the William M. Barret geophysical laboratory.

Principle of Operation

Concentrated paths of electrical energy are obtained in the manner illustrated in Fig. 6. Radio waves of the proper frequency are emitted by a transmitter, which is usually referred to as the "exciter," which directs a "surface wave," 1, along the air-earth boundary, 2. As the surface wave moves to the right, rays progressively are refracted at the interface and enter the subsurface along a multitude of parallel ray paths, such as path 3, and travel downward toward a reflecting formation 4. Formation 4, which may be a porous reservoir carrying salt water and/or oil, partially refracts the rays downward and partially reflects the rays back to the surface 2. The rays are again refracted at the air-earth interface to the receiver R. The reflected rays reaching the receiver are in space phase and time phase, and they therefore reinforce one another in actuating the receiver.

The lowest points of the subsurface ray paths are used to "scan" a reservoir for oil accumulations. The presence of oil causes a significant difference in the character of the reflected rays and the difference is made evident by mixing the reflected rays with the reference wave 1 which travels the earth's surface to the receiver.

Penetration of Radio Waves

Geophysicists and radio engineers have, until recently, believed that radio waves do not penetrate more than a few hundred feet into the earth. In order to disprove this criticism of its method, William M. Barret, Inc. demonstrated to a group of scientists that radio waves can be transmitted from a portable transmitter at the earth's surface to a receiver located at a depth of 700 ft in abandoned workings of the Kleer salt mine[6,7] at Grand Saline,

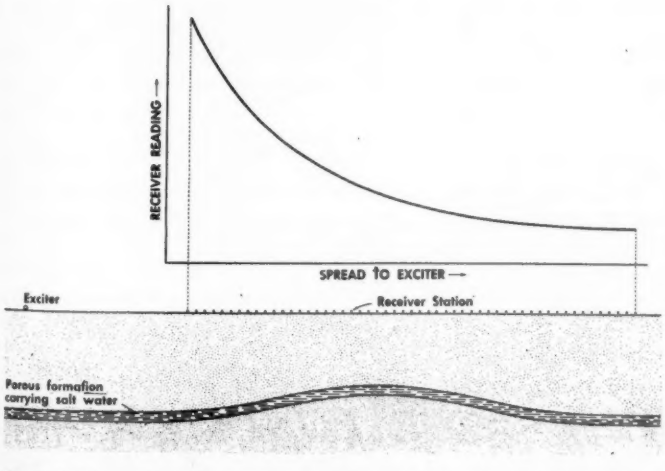

FIG. 7. Neutral profile over an anticline that carries no oil deposit.

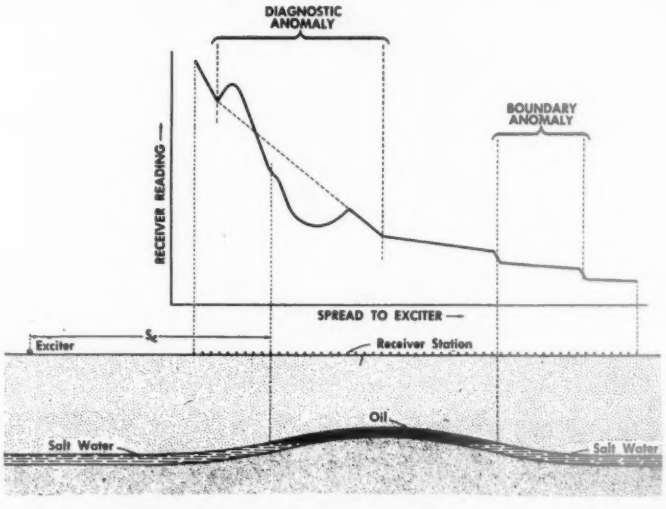

FIG. 8. Diagnostic and boundary anomalies over an oil deposit associated with an anticline.

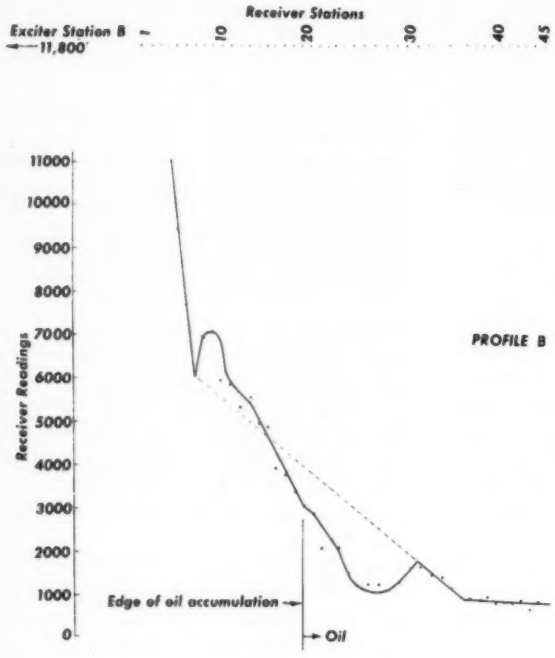

FIG. 9. Diagnostic anomaly observed over south boundary of Ada field, Webster and Bienville parishes, Louisiana.

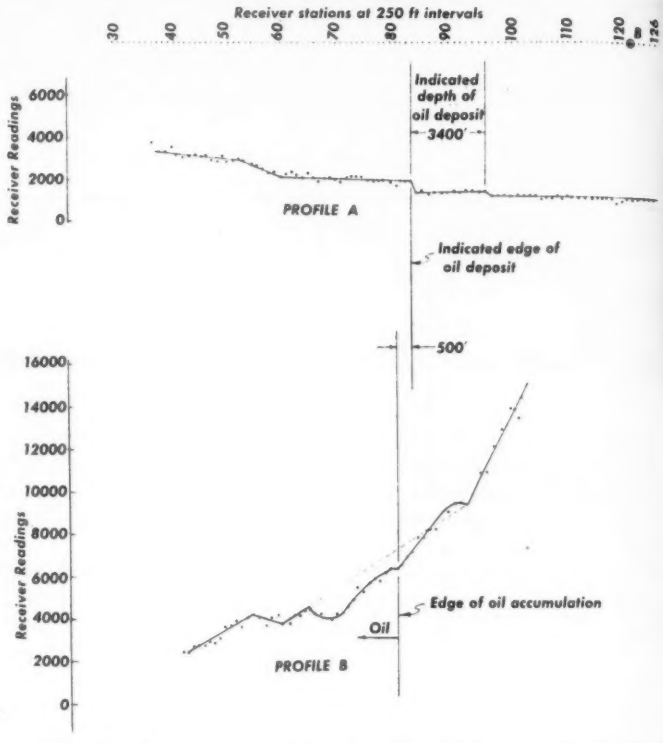

FIG. 10. Boundary anomaly and diagnostic anomaly observed over north boundary of Big Foot field of Frio County, Texas.

Texas. Strong signals were received from a small transmitter (radiated power of 1.5 w) after traveling through a complex geologic section 700 ft thick. Evidence seems to disprove the idea that the signals actually reached the receiver by traveling through the mine shaft. This test apparently showed that the Radoil method provides an effective mechanism for transmitting radio waves through the earth.

Oil boundaries lying at a depth of 9000 ft have been satisfactorily investigated. Probably the method may be applied effectively at greater depths.

Equipment

The instrumentation involved consists of an exciter and a receiver. The exciter, mounted in a light truck, generates electro-magnetic waves at a constant frequency and has a system of controls for keeping the amplitude constant. The antenna connected with the exciter is directional and is oriented in line with the profile being run.

The receiver is portable and designed to operate at constant gain when receiving the waves from the exciter. The receiver antenna is a square loop mounted on a Johnson-head tripod.

Field Procedure

In running a profile with this method, the exciter remains fixed in position while the receiver occupies successive stations away from the exciter. After a series of readings has been made on a particular profile the exciter is moved to another location and the receiver occupies stations along the same or a different profile. Considerable technique is required to manipulate the exciter and receiver placement, which is somewhat critical, to obtain the diagnostic anomaly that is the definite indication of an oil accumulation.

Character of Electrical Indications

When the exciter is in a certain position with respect to the edge of an oil accumulation, an anomaly of a characteristic type is found on the transmission curve (graph of signal intensity versus spread to exciter). A definite type of anomaly which is called a "diagnostic anomaly" is found over the near edge of the oil accumulation. On the same curve or on other curves a different type of anomaly is observed over the far edge of the accumulation which is called a "boundary anomaly."

If no oil is present beneath the profile a "neutral curve" is obtained. These characteristics are illustrated in Fig. 7 and 8. The dimensions of both the diagnostic and boundary anomalies change with the depth to the oil accumulation, which governs spacing between the exciter and the receiver stations. The farther they are spaced, the deeper the investigation.

The development of the diagnostic anomaly may be explained by wave reflection from the reservoir stratum ahead of the oil boundary, by "diffraction" at the boundary, by amplitude and time phase changes that occur between the rays reflected by the oil stratum, and by the mixing of the reflected waves with the surface wave.

Application of Method

The Radoil method is useful for determining if oil lies beneath an undrilled wildcat prospect located by other geophysical or geological methods. Also, the method will outline the areal extent of a wildcat oil accumulation thus allowing an estimation of reserves to be made before drilling.

Another application to which the method is especially adaptable is the mapping of the areal extent of oil deposits already established by one or more wells. With this procedure, called the "Radial-Traverse Method," traverses radiate from a centrally located exciter positioned near a discovery well, and the areal extent of the oil is found by interconnecting the boundary anomalies obtained along the radial traverses. The results obtained can be used to plan lease buying and the drilling of development wells.

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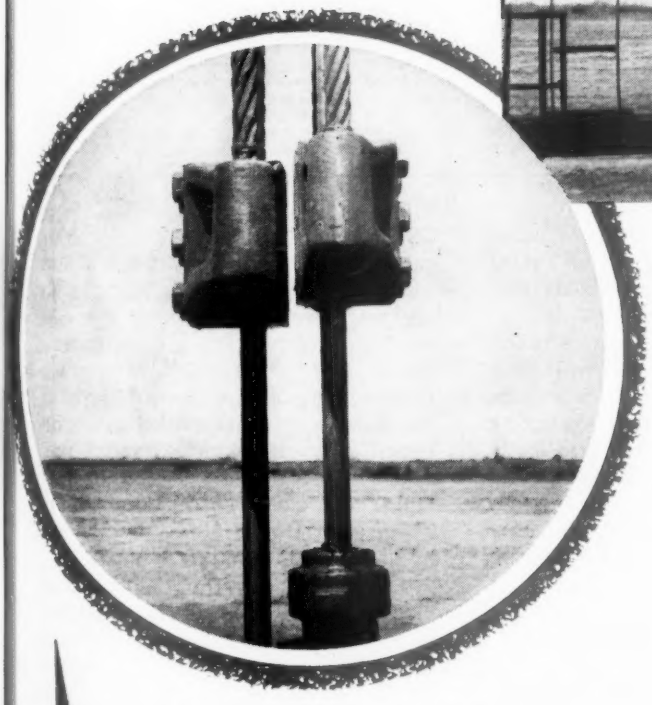

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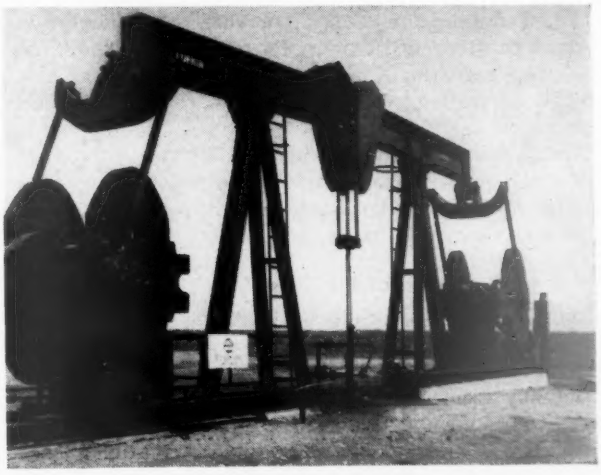

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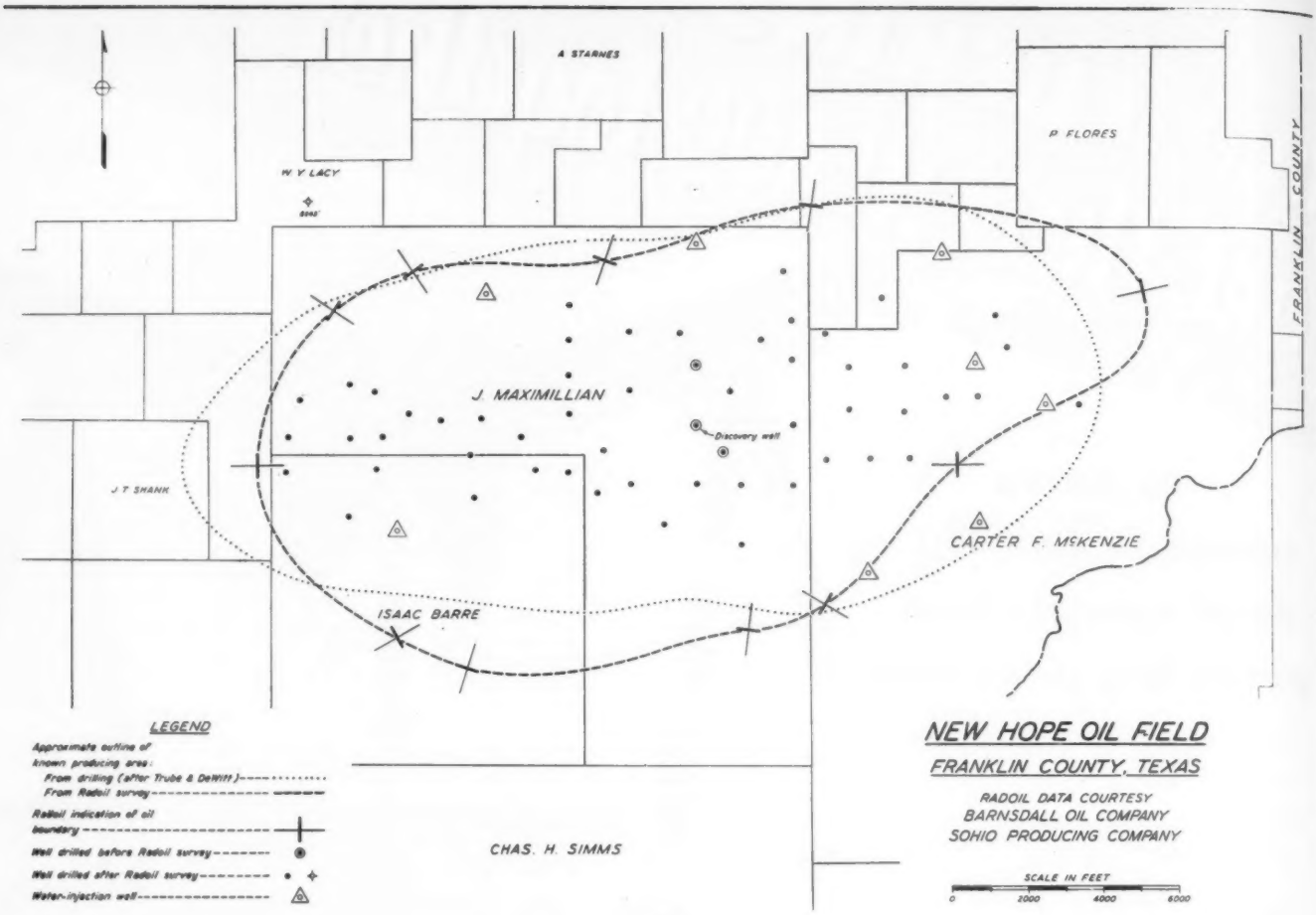

FIG. 11.

The approximate depth of the oil accumulation is said to be obtainable from the anomaly within five per cent, plus or minus, of the true depth. The S_e spread (exciter to near-boundary distance) and the length of the boundary anomaly are closely related to the depth of the accumulation and are used to estimate it.

Where multiple oil zones are vertically separated 500 ft or more, they may be individually located and mapped, according to William M. Barret, Inc.

The application of the Radoil method may result in the location of oil that lies in hitherto undetectable stratigraphic and structural traps.

Limitations

Radoil is a detailed method of prospecting, and cannot be used effectively as a reconnaissance method. Oil must be actually located directly below the profile or no indication will result, hence a reconnaissance profile would pass by an adjacent oil accumulation with no indication.

Since the method locates only the edges of the oil accumulations (it is the contrast between the electrical properties of the oil and the surrounding water or rock which produces the anomaly), no evidence of the oil would show up if the exciter and all the receiver stations were situated over an oil deposit.

Another important limitation is that the width of an oil deposit must be at least 1¼ times its depth below the surface in order to develop a diagnostic anomaly.[8] For smaller fields, the boundary anomaly may be used to define the limits of the oil accumulation, although this procedure is considered less reliable than when the diagnostic anomaly is employed.

Examples of Past Applications

In Fig. 9 is shown a Radoil profile which was obtained along a traverse that crossed over the Ada field,[8] Webster and Bienville parishes, Louisiana. This profile displays a diagnostic anomaly of acceptable character. The wells in this field are producing from a depth of about 6700 ft.

A profile to test the reception of the boundary anomaly was run on the Big Foot field[8] of Frio County, Texas. Oil had been discovered at a depth of about 3500 ft, and the field was believed to extend some distance to the east. Profiles were run about a mile east of the nearest drilling well. Profile A, in Fig. 10, was run from the south and Profile B, Fig. 10, was a reverse of the same profile. On the north end of Profile A a fairly strong boundary anomaly was received indicating the edge of an oil accumulation at depth of about 3400 ft. This indication was checked by running the profile backwards, in which case Profile B was obtained indicating the field edge only 500 ft from Profile A's indication. Note the close correlation of the depths proved by drilling and indicated by the method (3500 to 3400 ft).

February 4, 1944, marked the completion of the Radoil survey of the New Hope field[9] in Franklin County, Texas. This field contained four known oil reservoirs in the Trinity group of the Lower Cretaceous series lying at depths around 8000 ft. Near the end of 1943, William M. Barret, Inc. was retained by Barnsdall Oil Company and Sohio Producing Company to make a Radoil survey for the purpose of mapping the outer limits of the oil-saturated area then in production, without regard to the patterns of the individual reservoirs. Using the outermost electrical indications of acceptable grade (55 indications were used) a dashed outline was arrived at. Fig. 11 shows the New Hope field with the dashed Radoil outline and the production limit

as projected by six years of drilling (limit plotted by Trube and De Witt in their paper published in 1950). The two limits are in satisfactory agreement.

Over 50 oil fields scattered through the United States have been satisfactorily surveyed with good anomalies recorded.

Conclusion

The results of past work done with the Radoil method have been favorable, but further field studies are necessary to evaluate fully the limitations and possibilities. Once the method is generally accepted, it should be a valuable tool in proving the presence or absence of oil.

History shows that as one petroleum exploration method has faded, a new one has replaced it. Perhaps the radio method is about to make its appearance as an important geophysical tool.

Credits

Fig. 4 and 5 courtesy of World Oil and M. S. Blackburn.
Fig. 6, 7, 8 and 11 courtesy of Wm. M. Barrett, Inc.
Fig. 9 and 10 courtesy of World Oil and R. B. Pratt.

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* * *

Reservoir Engineering

A four-weeks course in basic reservoir engineering offered by the College of Mineral Industries of The Pennsylvania State University closed late in April with 20 engineers completing the course. The Seminar was attended by engineers from Pure, Sun, Socony-Mobil, Texas companies and Republic Natural Gas. Dr. John C. Calhoune, Jr., head of the department and David T. Oakes, instructor, of petroleum and natural gas engineering, headed the seminar.

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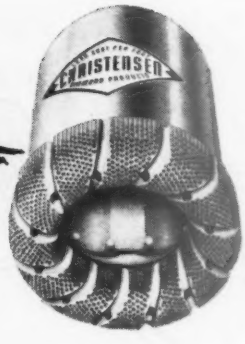

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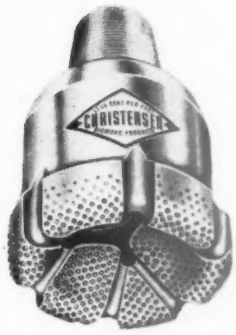

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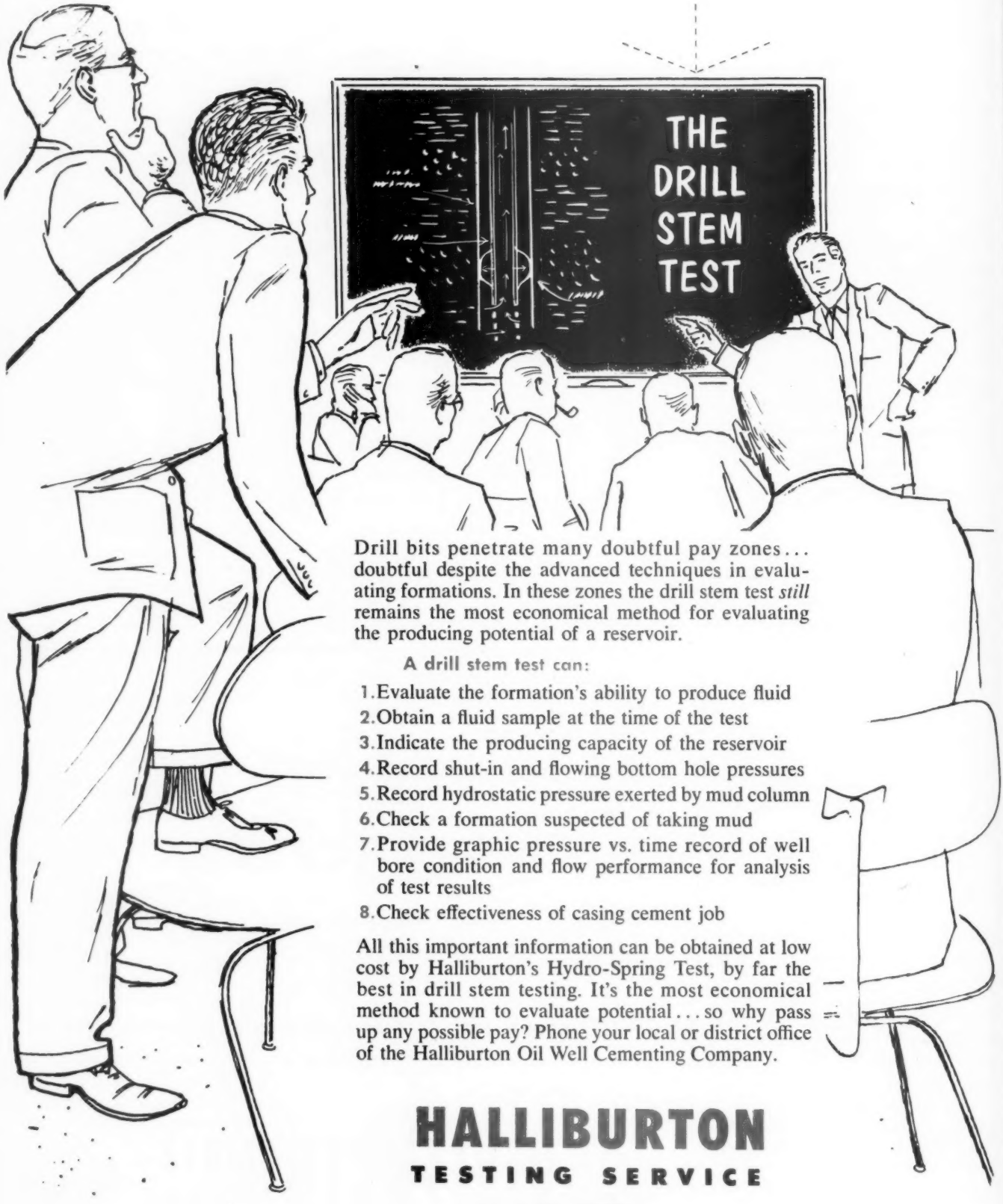

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Presentation of three numerical integrating procedures for estimating future action of solution gas drive formations

D. M. BASS and PAUL B. CRAWFORD

SOLUTION gas drive reservoirs constitute perhaps the most common type oil reservoir being produced today. They produce oil principally by virtue of the energy stored in the dissolved gas. The production performance curves of a solution gas drive reservoir are unique and may be distinguished from the performance curves of water drive or gas cap drive mechanisms. It is sometimes a difficult task, however, to determine the producing mechanism early in the life of the oil reservoir.

This is especially true when a combination solution gas and water drive are present. An oil reservoir producing primarily by solution gas drive may have a weak natural water drive, yet the presence of the latter may not be known until some intermediate stage in the life of the reservoir.

If there is no water drive and no gas cap present, the shape of the gas-oil ratio and pressure decline curves may be similar to those shown in Fig. 6. The peak gas-oil ratio may be slightly displaced to the right or left depending on the properties of the reservoir fluid and porous media. The usual solution gas drive reservoir, if permitted to produce of its own energy to its economic limit, may produce from 15 to 50 per cent of the original oil in place.

The actual oil recovery is determined largely by the properties of the reservoir fluids and the porous media. In realization that no two oil reservoirs are identical in every detail; each oil reservoir is unique and should be so treated. Broad generalizations concerning the effect of various properties on the oil recovered from the several types of reservoirs may lead to considerable variation between the postulated and observed result.

In solution gas drive reservoirs there are many properties of the reservoir and its contained fluids which effect the oil recovery. These properties include the oil and gas viscosities, fluid saturation distribution, permeabilities, oil shrinkage, etc., all of which have been related into a single equation by Muskat[4] from which the cumulative oil and gas production may be estimated.

Equation 1, which required many assumptions in its derivation and may have neglected parameters which observations will later validate, remains as the fundamental equation for predicting solution gas drive performance. The purpose of this paper is to illustrate and compare three methods of solving Muskat's equation.

$$\left(1+\frac{\mu o}{\mu g}\,\frac{kg}{ko}\right)\frac{d\rho o}{dP}=\rho o\left(\frac{1}{\gamma\beta o}\,\frac{dSo}{dP}\right)+(1-\rho o-\rho w)\times\left(\frac{1}{\gamma}\,\frac{d\gamma}{dP}\right)+\rho o\,\frac{kg}{ko}\left(\frac{\mu o}{\mu g\,\beta_o}\,\frac{d\beta o}{dP}\right) \quad . \; . \quad (1)$$

$$R=\left[So+(\gamma\beta o\,\frac{\mu o}{\mu g}\Psi)\right]5.61 \quad . \; . \quad (1a)$$

Where:

μo = viscosity of oil, cp.
μg = viscosity of gas, cp.
kg = effective gas permeability
ko = effective oil permeability
ρo = oil saturation, fraction of pore space
ρw = water saturation, fraction of pore space
P = reservoir pressure, psia
γ = relative gas density, scf/reservoir cu ft
βo = oil formation volume factor, res. bbl/stb,
R = producing gas-oil ratio, scf/stb
So = solubility gas-oil ratio, cu ft/cu ft
5.61 = conversion factor, cu ft/bbl

Equation 1 is not a simple differential equation and can only be solved analytically under special conditions; it is usually necessary to use graphical or numerical means for a solution. For ease in solving Muskat collected terms as functions of pressure, with which he rewrote equation 1 as follows:

$$(1+\frac{\mu o}{\mu g}\Psi)\,\frac{d\rho o}{dP}=\rho o\,\lambda(p)+(1-\rho o-\rho w)\,\varepsilon(p)+\rho o\,\Psi\,\eta\,(p) \quad . \; . \quad (2)$$

$$R=[So+\propto\Psi]\,5.61 \quad . \; . \; . \; . \quad (2a)$$

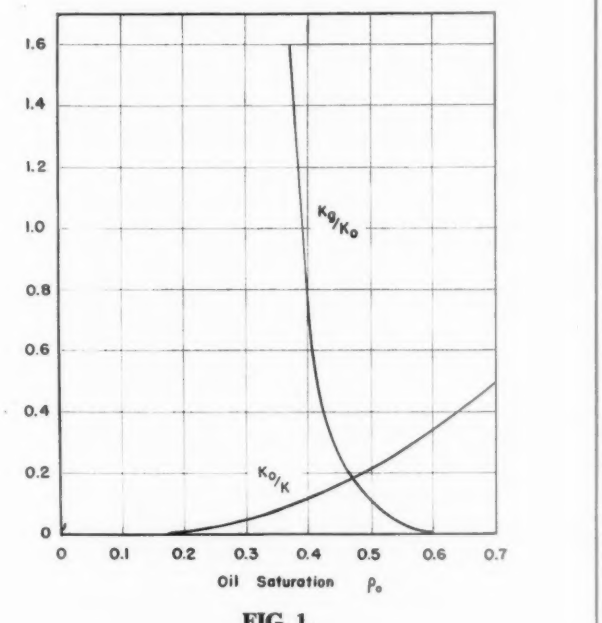

FIG. 1.

The Authors

Paul B. Crawford is assistant director of the Texas Petroleum Research Committee and is assigned to the Texas Agricultural and Mechanical College Division. Crawford joined American Cyanamide and Chemical Corporation after graduating from Texas Technological College with a BS degree in chemical engineering in 1943. He later received his MS and PhD in chemical engineering from the University of Texas. Crawford was formerly employed by Magnolia Petroleum Company in the field research laboratories and worked primarily on the In-Situ Combustion Recovery Process. He is the inventor of several innovations of the process. Crawford is a member of the A and M College Graduate Faculty and is a professional engineer.

P. B. Crawford

D. M. Bass

D. M. Bass is associate research technologist in the A and M College Division of the Texas Petroleum Research Committee. He has been primarily engaged in studying high pressure waterflooding recoveries from solution gas-drive reservoirs. A graduate of Louisiana State University with a BS degree in petroleum engineering, Bass was formerly with Magnolia Petroleum Company as a petroleum engineer.

Where:

$$\Psi = \frac{kg}{ko} \text{(psi, a function of saturation)} \quad . \quad . \quad . \quad (3a)$$

$$\lambda\,(p) = \frac{1}{\gamma\,\beta\,o}\,\frac{dS_o}{dP} \text{(lambda, a function of pressure)}$$

$$. \quad (3b)$$

$$\varepsilon\,(p) = \frac{1}{\gamma}\,\frac{d\,\gamma}{dP} \text{(epsilon, a function of pressure)} \quad . \quad (3c)$$

$$\eta\,(p) = \frac{\propto}{\gamma\beta o^2}\,\frac{d\,\beta\,o}{dP} \text{(eta, a function of pressure)} \quad . \quad (3d)$$

$$\propto\,(p) = \frac{\mu o}{\mu g}\,\gamma\,\beta\,o \text{ (alpha, a function of pressure)} \quad (3e)$$

In estimating reservoir performance, equation 1 is generally applied to the reservoir as a unit (without considering localized variations). Where sufficient data are available it may sometimes be applied, however, with a higher degree of accuracy, to a small segment of a reservoir, i.e., a lease. In the latter case anomalies of pressure and saturation can be taken into consideration, but caution should be exercised to insure that a proper drainage area is used for the lease. In large reservoirs it is a generally accepted practice to divide the reservoir into segments of similar characteristics and solve the equation for each segment individually.

Equation 1 shows that the change in reservoir oil saturation with pressure is equal to the sum of three terms divided by the sum of two terms. The right hand side of the equation has three terms $\gamma(p)$, ε (p) and $\eta(p)$, all of which are functions of reservoir pressure. The value of these functions must be known at each pressure in order to solve the equation. Means of securing the required data and its preparation for solving the equation are indicated below.

Methods of Solving Solution Gas Drive Equation

Laboratory and/or Field Data. In order to apply equation 1, it is normally required that the following information be obtained on the reservoir: The pore volume of the reservoir, the average initial reservoir pressure, and the volume per cent of oil, water, and gas in the pore volume. Since at the time most engineers are assigned to estimate the performance of a solution gas drive reservoir or lease, the reservoir is in intermediate stage of depletion, the following methods will show the data and procedure required in estimating the future production characteristics from any stage in the reservoir life.

Other reservoir and fluid properties required in making the calculations include:

Values of k_g/k_o as a function of oil saturation; in lieu of suitable field data it is suggested that laboratory data from respresentative core samples be used. Typical data are shown in Fig. 1.

Ratios of the viscosity of oil to gas as a function of pressure; this can perhaps be provided by laboratory data on the particular reservoir fluids. Such data are shown plotted in Fig. 2.

Solubility of the gas in the oil at various pressures up to reservoir pressure; shown in Fig. 3.

Density of the reservoir gas at various pressures up to reservoir pressure; shown in Fig. 4.

Formation volume factors of the oil at various pressures up to reservoir pressure, shown in Fig. 3.

The above data should be obtained at the reservoir temperature.

With the exception of the permeability and gas viscosity data, most of the other information is normally supplied in tabular and graphical form in standard fluid analyses from petroleum engineering laboratories.

Preparation of the Data. After the above data have been secured the remaining effort consists primarily in preparing the tables and graphs necessary in facilitating the calculations. The evaluation of the functions $\propto$, $\lambda(p)$, $\varepsilon(p)$ and $\eta(p)$ are particularly significant.

Evaluation of alpha, $\propto$(p)

Referring to equation (3) it will be seen that

$$\propto = \gamma\,\beta\,o\,\frac{\mu o}{\mu g}$$

As each member of the term on the right hand side of the the equation is a function of pressure, it is suggested that three curves be plotted with pressure as abscissa (X-axis) and with γ, β_o and $\frac{\mu_o}{\mu_g}$ as the ordinates (Y-axis) respectively. A table, such as Table 1, is prepared with reservoir pressure as the first column, γ as the second column, β_o as the third column, $\frac{\mu_o}{\mu_g}$ as the fourth column, and $\propto$ as the last column.

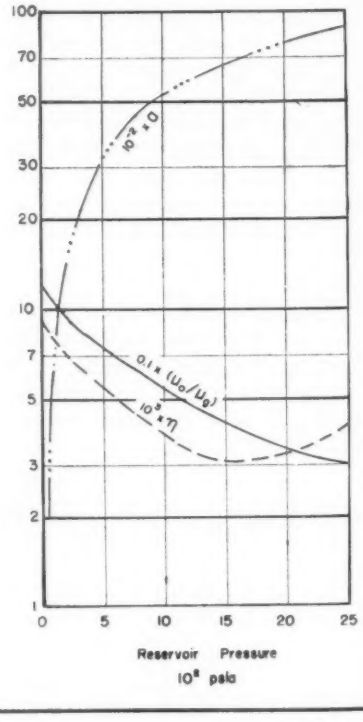

FIG. 2.

Figures 1 through 5 reproduced after Muskat "Physical Principles of Oil Production" (McGraw Hill—1949) page 412.

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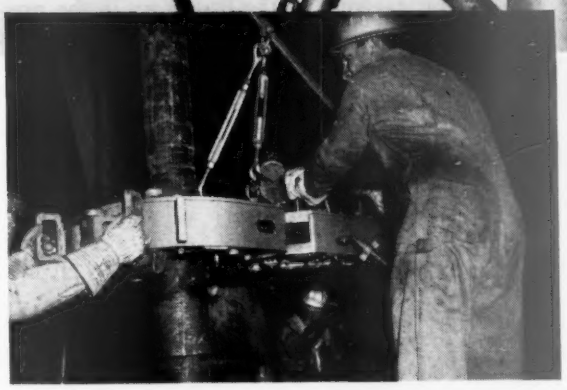

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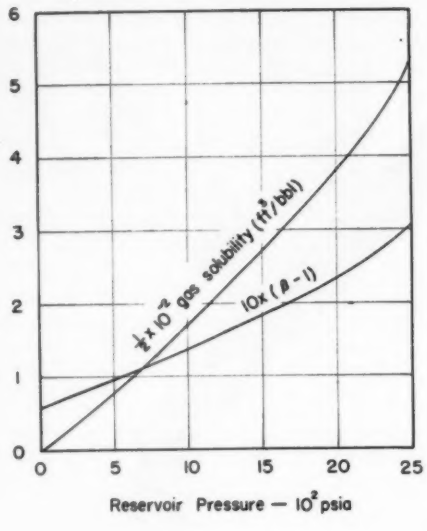

FIG. 3.

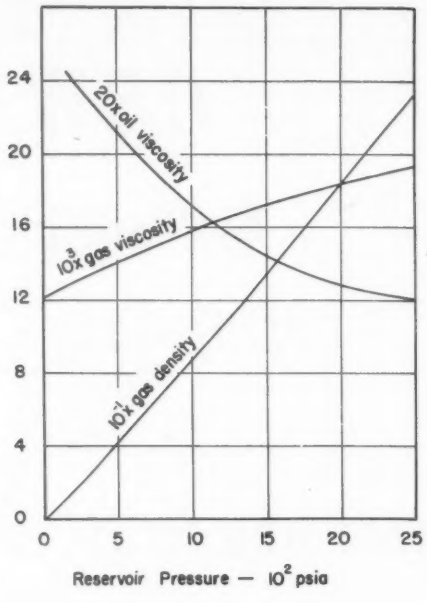

FIG. 4.

TABLE 1. Suggested table form for evaluating alpha.

P	γ	β_o	μ_o/μ_g	α
2500	236	1.308	30	9250
2250	215	1.265	31	8450
2000	187	1.235	34	7850
1750	168	1.207	36	7300
1500	139	1.185	41	6750
1250	112	1.161	46	6000
1000	87.1	1.137	53	5250
750	62.9	1.115	62	4350
500	41.8	1.098	73	3350
250	20.9	1.077	89	2000

Beginning with reservoir pressure or a convenient increment above reservoir pressure as the first entry in the pressure column, then proceed to form a diminishing arithmetic series using a convenient difference in pressure, such as 2500, 2250, 2000, etc. Using the 3 previously prepared graphs of γ, β_o and $\frac{\mu_o}{\mu_g}$ insert their proper values in the table opposite the column of pressures. Solve equation 3 for the proper values of α. Plot a curve of α versus pressure. This is shown in Fig. 2.

Evaluation of eta, η(p)

The term η(p) is given by:

$$\eta(p) = \frac{\alpha}{\gamma\, \beta o^2} \frac{d\,\beta_o}{dP}$$

A suggested procedure for evaluation eta, η(p), is indicated here. Prepare a table with columnar headings similar to Table 2.

In Table 2 column 1 represents the reservoir pressure and should be tabulated in a decreasing arithmetic series, i.e., with a constant increment: an increment of 250 psia is shown here. Column 2 represents the difference in successive pressure increments of column 1. The third column shows the values of β_o at various pressures. In the fourth column $\Delta\beta_o/\Delta P$ represents the difference between successive entries in column 3. Column 5 is obtained by dividing each entry in column 4 by the values in column 2. Column 6 represents the **average** pressure at which column 5 holds true.

Pressure values in column 6 are equal to those in column 1 minus ½ Δ P. Columns 7, 8, and 9 represent the values of α, γ, and β_o at the pressures shown in column 6. To compute eta, η(p), multiply the ratio in column 5 by the term in column 7, divide by the term in column 8 and the square of the term in column 9. After obtaining η(p), column 10 a graph should be prepared of η versus pressure values from columns 10 and 6 respectively.

TABLE 2. Suggested table form for evaluating Eta.

1 P	2 ΔP	3 β_o *	4 $\Delta\beta_o$	5 $\frac{\Delta\beta_o}{\Delta P}$	6 Pave	7 α	8 γ	9 β_o at Pave	10 η(P) × 10^2
2625		1.3300							
2375	250	1.2855	0.0445	0.000178	2500	9250	236	1.308	0.410
2125	250	1.2477	0.0378	0.000151	2250	8450	215	1.265	0.370
1875	250	1.2177	0.0300	0.000120	2000	7850	187	1.235	0.330
1625	250	1.1917	0.0260	0.000104	1750	7300	168	1.207	0.310
1375	250	1.1692	0.0225	0.0000899	1500	6750	139	1.185	0.310
1125	250	1.1487	0.0205	0.0000820	1250	6000	112	1.161	0.325
875	250	1.1285	0.0202	0.0000809	1000	5250	87.1	1.137	0.375
625	250	1.1083	0.0202	0.0000809	750	4350	62.9	1.115	0.450
375	250	1.088	0.0203	0.0000812	500	3350	41.8	1.098	0.540
125	250	1.0680	0.0200	0.0000800	250	2000	20.9	1.077	0.660

*For $\Delta\beta_o$ to be accurate to three digits it is necessary that β_o be plotted so that it can be read to the accuracy shown.

Evaluation of Lambda, λ(p)

The following expression represents λ(p):

$$\lambda(p) = \frac{dSo}{\lambda\beta_o\, dP}$$

The value of λ may be determined by a similar procedure as that described for η. A suggested tabular form to aid in the calculation is shown in Table 3.

TABLE 3. Suggested table form for evaluating lambda.

1 P	2 ΔP	3 S_o	4 ΔS_o	5 * $[\Delta S_o/5.61\Delta P]$	6 Pave	7 γ	8 β_o	9 λ(P) × 10^3
2625		1160.6						
2375	250	979.6	191	0.136	2500	236	1.308	0.440
2125	250	831.6	148	0.105	2250	215	1.265	0.385
1875	250	708.6	123	0.0877	2000	187	1.235	0.380
1625	250	593.1	115.5	0.0832	1750	168	1.207	0.410
1375	250	486.6	106.5	0.0758	1500	139	1.185	0.460
1125	250	387.9	98.7	0.0703	1250	112	1.161	0.54
875	250	294.8	93.1	0.0664	1000	87.1	1.137	0.67
625	250	208.3	86.5	0.0616	750	62.9	1.115	0.88
375	250	121.3	87.0	0.0620	500	41.8	1.098	1.35
125	250	31	90.3	0.0642	250	20.9	1.077	2.85

* The constant 5.61 converts from cu ft/bbl to cu ft/cu ft.

It should be pointed out that columns 7 and 8 (Table 3) should be the values occurring at the pressures shown in column 6. Column 9 should be plotted versus column 6. This is shown in Fig. 5.

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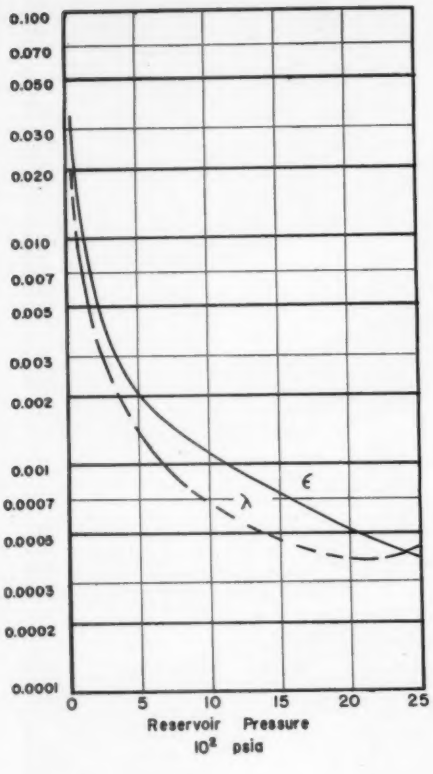

FIG. 5.

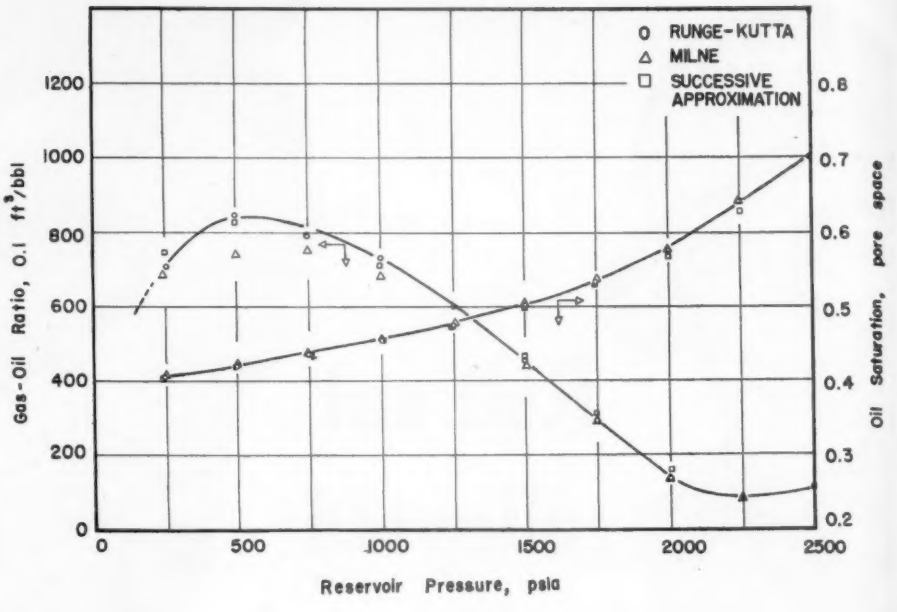

FIG. 6.

Evaluation of epsilon, $\varepsilon(p)$

The value of $\varepsilon(p)$ is given by the following relation:

$$\varepsilon(p) = \frac{1}{\gamma}\frac{d\gamma}{dP}$$

The above may be evaluated by a similar procedure as that described for $\eta(p)$. A suggested table to aid in the calculation is shown below as Table 4.

TABLE 4. Suggested table form for evaluating epsilon.

1 P	2 ΔP	3 γ	4 Δγ	5 Δγ/ΔP	6 Pave	7 γ	8 1/γ	9 ε(ρ)×10³
2625		245.0						
2375	250	223.2	21.8	0.0874	2500	236	0.00424	0.370
2125	250	200.1	23.1	0.0925	2250	215	0.00465	0.430
1875	250	176.3	23.8	0.0954	2000	187	0.00535	0.510
1625	250	150.3	26.0	0.1042	1750	168	0.00595	0.620
1375	250	124.3	26.0	0.1042	1500	139	0.00720	0.750
1125	250	99.1	25.2	0.1009	1250	112	0.00893	0.900
875	250	75.2	23.9	0.0958	1000	87.1	0.01148	1.10
625	250	52.8	22.4	0.0893	750	62.9	0.0159	1.44
375	250	31.4	21.4	0.0857	500	41.8	0.0239	2.05
125	250	10.5	21.9	0.0878	250	20.9	0.0479	4.20

Column 7 (Table 4), should show the values γ occurring at the pressures shown in column 6. A plot should be made of column 6 versus column 9. This is shown in Fig. 5.

The solution gas drive equation 2 may be solved by several methods, and it is a purpose of this paper to describe and compare three of these methods.* All of the methods presented here represent approximate solutions; however, the degree of accuracy of these methods is probably greater than the reproducibility of core and fluid analysis data. Any one of the methods described here may be applied to a reservoir or lease in a fairly short time.

The methods which are presented here for solving the solution gas drive equation are not new. They were originally presented in the literature some 50 years ago.[1,2,3,5] In realization that the reservoir engineer may not have the time nor opportunity to find and review these methods, this paper has been prepared to illustrate these published means of solving Muskat's solution gas drive equation.

*Muskat suggested the use of the Milne and Runge-Kutta methods in solving the solution gas drive equation.

Method of Successive Approximations. Of the three methods presented here the method of successive approximations is perhaps the most universally known and used.[6] In its application it is necessary to have sufficient data at initial conditions with which the slope $\left(\frac{d\rho_o}{dP}\right)_1$ can be determined. After determining the initial slope and choosing the pressure increment (ΔP), successive values of oil saturation (ρ_o, rho) are obtained in the following manner:

For trial value of ρ_o at $P_2 = P_1 - \Delta P$

$$_1(\rho_o)_2^{**} = (\rho_o)_1 - \left(\frac{d\rho o}{dP}\right)_1 \Delta P \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Solve equation 2 for $\frac{d\rho_o}{dP}$ using values $\eta(p)$, $\varepsilon(p)$, $\lambda(p)$, $\Psi(\rho_o)$ and μ_o/μ_g as determined by $(P)_2$ and $_1(\rho_o)_2$. Using the new value of the slope $\left(\frac{d\rho_o}{dP}\right)_2$ determine the second trial value of the oil saturation $_2(\rho o)_2$ as follows:

$$_2(\rho o)_2 = (\rho o)_1 - \left[\frac{\left(\frac{d\rho o}{dP}\right)_1 + {}_1\left(\frac{d\rho o}{dP}\right)_2}{2}\right]\Delta P \,. \quad (5)$$

Solve equation 2 using pertinent values corresponding to the oil saturation $_2(\rho o)_2$ and obtain the value of the new slope $_2\left(\frac{d\rho o}{dP}\right)_2$ at $_2(\rho_o)_2$. Solve equation 6

$$_3(\rho o)_2 = (\rho_o)_1 - \left[\left(\frac{d\rho o}{dP}\right)_1 + {}_2\left(\frac{^o d p}{dP}\right)_2\right]\frac{\Delta P}{2}. \quad (6)$$

for a new value of the oil saturation at P_2. This procedure is continued until the values of $_{n-1}(\rho o)_2$ and $_n(\rho o)_2$ are identical to the desired number of significant figures.

**$_1(\ )_2$ The subscript on the right of the parenthesis represents the point being solved for; the subscript on the left represents the sequence of trial values used to determine the correct value.

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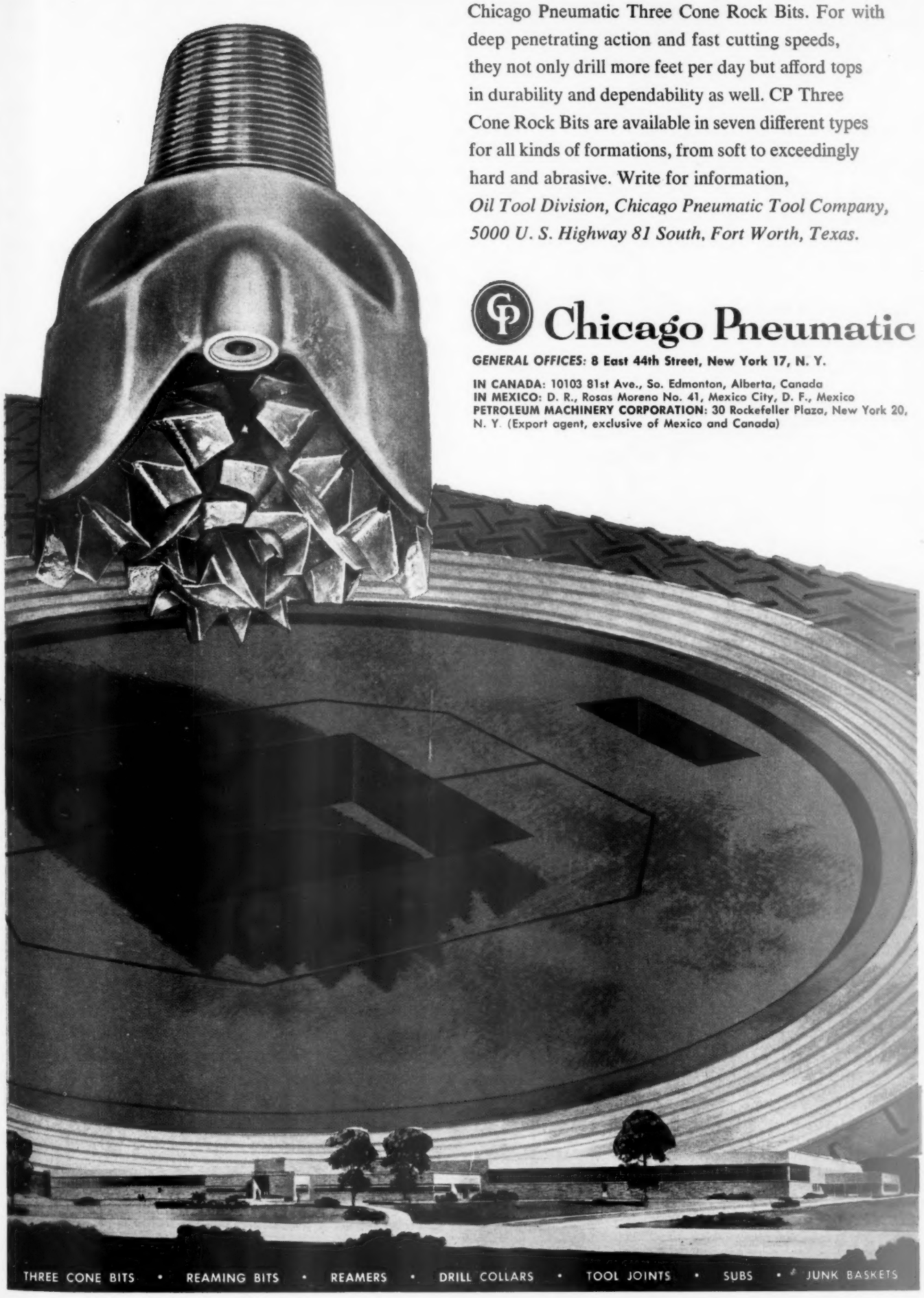

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A sample calculation of this method follows:

$(\rho o)_1 = 0.700$
$P_1 = 2500$ psia

$$\left(\frac{d\,\rho o}{d\,P}\right)_1 = \frac{\lambda(p)\,\rho o + (1 - \rho o - \rho w)\,\varepsilon(p) + \eta(p)\,\rho o\,\Psi}{\left(1 + \frac{\mu g}{\mu o}\Psi\right)} \qquad (2)$$

$$\left(\frac{d\,\rho o}{d\,P}\right)_1 = \frac{(0.00044)\,0.7 + (1 - 0.7 - 0.3)0.00037 + (0.0041)(0.7)(0)}{1 + (30)(0.0)} = 0.000308$$

with $\Delta P = 250$ psi
${}_1(\rho_o)_2 = 0.7 - (0.000308)\,250 = 0.623$ (first trial)
with $\rho o = 0.623$ and $P = 2250$

$${}_1\left(\frac{d\,\rho o}{d\,P}\right)_2 = \frac{(0.000385)\,0.623 + (1 - 0.623 - .3)\times(0.00043) + (0.0037)(0.623)(0)}{1 + (31)(0.0)} = 0.000273$$

Then

$${}_2(\rho o)_2 = 0.7 - \left[\frac{0.000308 + 0.000273}{2}\right]250 = 0.6275 \text{ (second trial)}$$

Then

$${}_2\left(\frac{d\,\rho o}{d\,P}\right)_2 = \frac{(0.000385)\,0.6275 + (1 - 0.6275 - 0.3)\times(0.00043) + (0.0037)(0.6275)(0)}{1 + 31\,(0)} = 0.000273$$

Then

$${}_3(\rho o)_2 = 0.7 - \frac{0.000308 + 0.000273}{2}\times(250) = 0.6275 \text{ (third trial)}$$

As ${}_2(\rho o)_2$ and ${}_3(\rho o)_2$ are identical through the first 4 digits, 0.6275 can be used as the oil saturation at a reservoir pressure of 2250 psia.

The same procedure is followed in solving for the oil saturation at the next lower reservoir pressure, that is where

$$P_3 = P_1 - 2\,\Delta P = P_2 - \Delta P \qquad (7)$$

Then

$${}_1(\rho o)_3 = {}_3(\rho o)_2 - {}_3\left(\frac{d\,\rho\,o}{d\,P}\right)_2 \Delta P \qquad (8)$$

$${}_2(\rho o)_3 = {}_3(\rho o)_2 - \left[\frac{{}_3\left(\frac{d\rho o}{d\,P}\right)_2 + {}_1\left(\frac{d\rho o}{d\,P}\right)_3}{2}\right]\Delta P \qquad (9)$$

$${}_3(\rho o)_3 = {}_3(\rho o)_2 - \left[{}_3\left(\frac{d\rho o}{d\,P}\right)_2 + {}_2\left(\frac{d\rho o}{d\,P}\right)_3\right]\frac{\Delta P}{2} \qquad (10)$$

The values of the slopes are obtained in each case by solving equation 2. This procedure is continued stepwise for each successive pressure until the oil saturation at the lowest pressure of interest has been computed. The calculated results are given in Table 5 and presented graphically in Fig. 6.

The gas-oil ratios may be readily computed by equation 2 for each pressure of interest.

$$R = [S_o + \propto \Psi]\,5.61 \qquad (2a)$$
$$= [189.9 + (9250)(0)]\,5.61$$
$$= 1065 \text{ cu ft/bbl}$$

Runge-Kutta Method. The Runge-Kutta is one of the older method of numerical integration.[2, 5, 6] It is more laborious than the other methods presented here but is believed to give a higher degree of accuracy than the method of successive approximations. In using this method it is necessary to solve equation 2 using the initial values ε, η, λ, etc. to obtain a value of the slope $\left(\frac{d\rho o}{d\,P}\right)_1$. The value of the oil saturation at P_2 is obtained in the following manner:

$$\text{let } (\Delta\,\rho o)_1 = \left(\frac{d\rho o}{d\,P}\right)_1 \Delta P \qquad (11)$$

Solve equation (2) using

$$\rho o = (\rho o)_1 - \left(\frac{\Delta\,\rho o}{2}\right)_1 \qquad (12)$$

$$\text{for } P = P_1 - \frac{\Delta P}{2} \qquad (13)$$

Obtaining a new slope ${}_1\left(\frac{d\rho o}{d\,P}\right)_2$

$$\text{let } (\Delta\,\rho o)_2 = {}_1\left(\frac{d\rho o}{d\,P}\right)_2 \Delta P \qquad (14)$$

and again solve equation (2) using $\rho o = (\rho o)_1 - \left(\frac{\Delta\,\rho o}{2}\right)_2$ (15)

$$\text{for } P = P_1 - \frac{\Delta P}{2} \qquad (13)$$

Obtaining another value for the slope ${}_2\left(\frac{d\rho o}{d\,P}\right)_2$

$$\text{let } (\rho o)_3 = {}_2\left(\frac{d\rho o}{d\,P}\right)_2 \Delta P \qquad (16)$$

and solve equation (2) using

$$\rho o = (\rho o)_1 - (\Delta\,\rho o)_3 \qquad (17)$$

$$\text{for } P = P_1 - \Delta P \qquad (18)$$

Obtaining ${}_3\left(\frac{d\rho o}{d\,P}\right)_2$

$$\text{Let } (\Delta\rho o)_4 = {}_3\left(\frac{d\rho o}{d\,P}\right)_2 \Delta P \qquad (19)$$

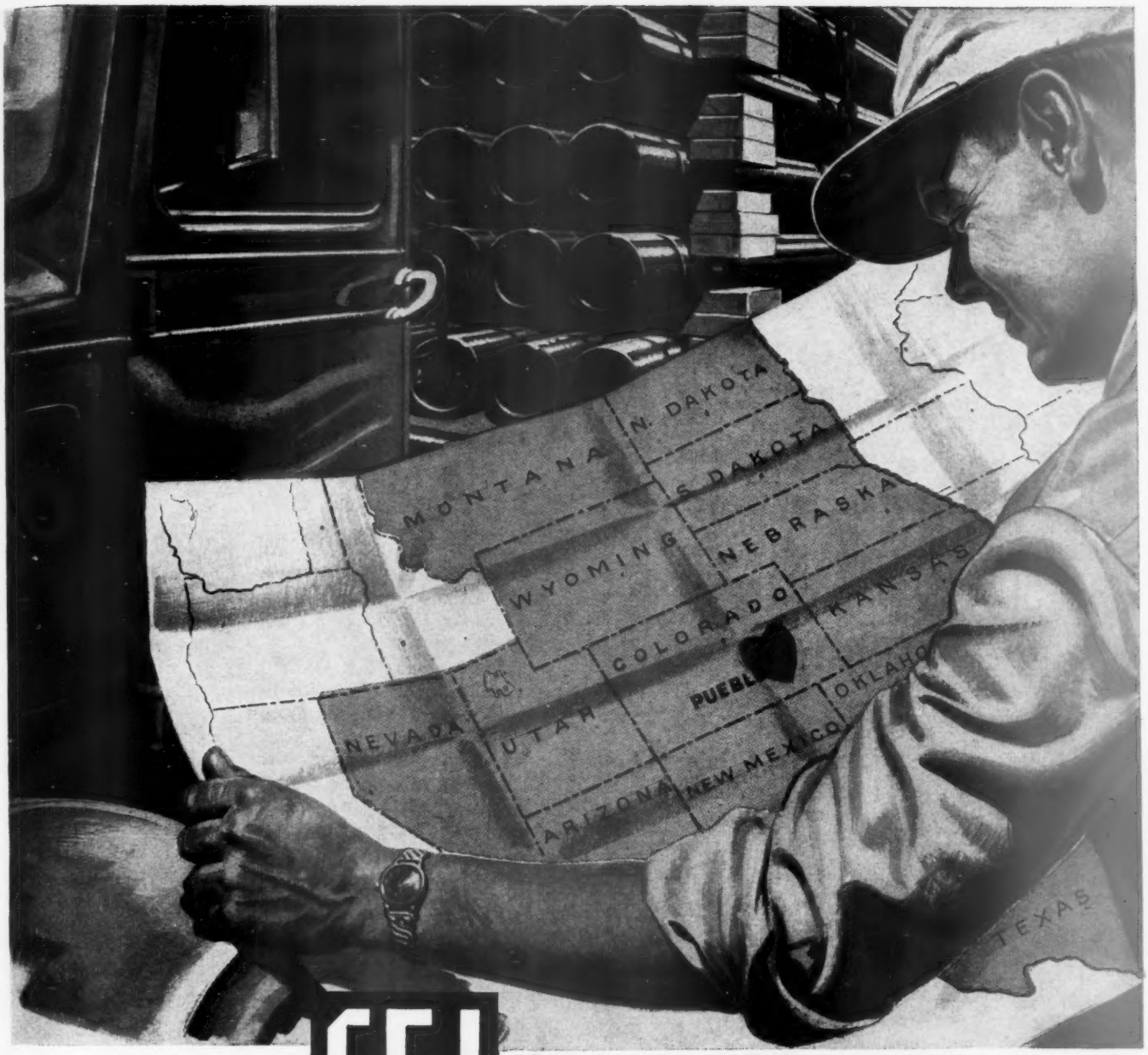
and solve the following equation for the value of the oil saturation at P_2.

$$(\rho o)_2 = (\rho o)_1 - \frac{1}{6}\left[(\Delta\rho o)_1 + 2(\Delta\rho o)_2 + 2(\Delta\rho o)_3 + (\Delta\rho o)_4\right] \qquad (20)$$

$$P_2 = P_1 - \Delta P \qquad (18)$$

After determining the value of $(\rho o)_2$ at P_2, solve for $(\rho o)_3$ at P_3 by the same procedure as above: that is

$$(\Delta\,\rho o)_1 = \left[{}_4\left(\frac{d\rho o}{d\,P}\right)_2\right]\Delta P \qquad (21)$$



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$$(\Delta\rho o)_2 = \left[{}_1\left(\frac{d\rho o}{d P}\right)_3 \right] \Delta P \quad \text{. . . . .} \quad (22)$$

Where

$$\rho o = (\rho o)_2) - \frac{(\Delta \rho o)_1}{2} \quad \text{. . . . .} \quad (23)$$

$$P = P_2 - \frac{\Delta P}{2} \quad \text{. . . . .} \quad (24)$$

Then

$$(\Delta\rho o)_3 = \left[{}_2\left(\frac{d\rho o}{d P}\right)_3 \right] \Delta P \quad \text{. . . . .} \quad (25)$$

Where

$$\rho o = (\rho o)_2 - \frac{(\Delta \rho o)_2}{2} \quad \text{. . . . .} \quad (26)$$

$$P = P_2 - \frac{\Delta P}{2} \quad \text{. . . . .} \quad (24)$$

Then

$$(\Delta\rho o)_4 = \left[{}_3\left(\frac{d\rho o}{d P}\right)_3 \right] \Delta P \quad \text{. . . . .} \quad (27)$$

Where

$$\rho o = (\rho o)_2 - (\Delta\rho o)_3 \quad \text{. . . . .} \quad (28)$$

$$P = P_2 - \Delta P \quad \text{. . . . .} \quad (29)$$

$$\text{then } (\rho o)_3 = (\rho o)_2 - 1/6\,[(\Delta\rho o)_1 + 2(\Delta\rho o)_2 + 2(\Delta\rho o)_3 + (\Delta\rho o)_4] \quad \text{. . . . . .} \quad (30)$$

$$P_3 = P_2 - \Delta P \quad \text{. . . . .} \quad (31)$$

An illustration follows:

$P_1 = 2500$ psia $\quad (\rho o)_1 = 0.7 \quad \rho w = C = 0.3$

$\left(\frac{d\rho o}{d P}\right)_1 = .000308$ as determined in the previous example.

$(\Delta\rho o)_1 = (.000308)\,(250) = .077$

$$\rho o = .7 - \frac{.077}{2} = .6615 \qquad P = 2500 - \frac{250}{2} = 2325$$

Solve equation 2 with the above values

$${}_1\left(\frac{d\rho o}{d P}\right)_2 = \frac{[(0.0004)\,(0.6615) + (1 - 0.6615 - 0.3)\,0.0004 + (O.0039) \times (0.6615)\,(0)]}{[1 + (30.5)\,(0)]}$$

$${}_1\left(\frac{d\rho o}{d P}\right)_2 = 0.00021$$

$$(\Delta\rho o)_2 = {}_1\left(\frac{d\rho o}{d P}\right)_2 \Delta P = (.00021)\,(250) = 0.0525$$

$$\rho o = 0.7 - \frac{.0525}{2} = 0.6727 \qquad P = 2500\text{-}250/2 = 2325$$

$${}_2\left(\frac{d\rho o}{d P}\right)_2 = [(0.0004)\,(0.6727) + (1 - 0.6727 - 0.3) \times (0.0004) + (0.0093)\,0.6727\,(0)] \div [1 + 30.5\,(0)] = 0.00021$$

for which

$$(\Delta\rho o)_3 = {}_2\left(\frac{d\rho o}{d P}\right)_2 \Delta P = (0.00021)\,(250) = 0.0525$$

$$\rho o = 0.7 - 0.0525 = 0.6475 \qquad P = 2500 - 250 = 2250$$

Using the above values of ρo and P

Then

$${}_3\left(\frac{d\rho o}{d P}\right)_2 = [(0.000385)\,(0.6475) + (1 - 0.6475 - 0.3)\,0.00043 + 0.0037 \times (0.6475)\,(0)] \div [1 + (31)\,(0)] = 0.000272$$

for which

$$(\Delta\rho o)_4 = {}_3\left(\frac{d\rho o}{d P}\right)_2 \Delta P = (0.000272)\,(250) = 0.068$$

The oil saturation $(\rho o)_2$ at a reservoir pressure of 2250 psia is given by:

$$(\rho o)_2 = (\rho o)_1 - 1/6\,[(\Delta\rho o)_1 + 2(\Delta\rho o)_2 + 2(\Delta\rho o)_3 + (\Delta\rho o)_4] \quad \text{. . . . .} \quad (20)$$

$$= 0.7 - 1/6\,[0.077 + 2\,(0.0525) + 2\,(0.0525) + 0.068]$$

$$(\rho o)_2 = 0.6408$$

$$P_2 = P_1 - \Delta P = 2500 - 250 = 2250 \text{ psia}$$

It is necessary to solve equation 2 with the above values of the oil saturation and reservoir pressure in order to determine the value of $(\Delta\rho o)_1$ used in obtaining the oil saturation at a reservoir pressure of 2000 psia. The remaining $(\Delta\rho o)$ values are obtained in the same manner as above except 0.6408 is used for (ρo) in place of 0.7 and 2250 is used for (P) in place of 2500.

Milne Method. The Milne[3,6] method of solving the type of equation under discussion requires that the first four values of the oil saturation at four pressure points be determined by some other method. These values may be obtained by either of the two methods already discussed or from data obtained by solving the material balance equation on past field history. To obtain points representing a state of further depletion it is necessary to solve the following equations.

$${}_1(\rho_o)_n = (\rho_o)_{n-4} - \frac{4\Delta P}{3}\left[2\left(\frac{d\rho_o}{d P}\right)_{n-1} - \left(\frac{d\rho_o}{d P}\right)_{n-2} + 2\left(\frac{d\rho_o}{d P}\right)_{n-3} \right] \quad \text{. . . . .} \quad (32)$$

$$P_n = P_1 - [(n - 1)\,\Delta P] \quad \text{. . . . .} \quad (33)$$

Solve equation 2 using the above determined values of (ρo) and (P) and obtain a value for the slope at P_n of ${}_1\left(\frac{d\rho o}{d P}\right)_n$. Using the value of the slope solve the following equation for another value of $(\rho_o)_n$.

$${}_2(\rho o)_n = (\rho_o)_{n-2} - \frac{\Delta P}{3} \times \left[{}_1\left(\frac{d\rho o}{d P}\right)_n + 4\left(\frac{d\rho o}{d P}\right)_{n-1} + \left(\frac{d\rho o}{d P}\right)_{n-2} \right] \quad \text{. .} \quad (34)$$

$$P_n = P_1 - [\,(n - 1)\,\Delta P\,] \quad \text{. . . . .} \quad (35)$$

An equation, developed by Milne, for determining the error of this method is:

$$E = \left[\frac{{}_2(\rho o)_n - {}_1(\rho o)_n}{29} \right] \quad \text{. . . . .} \quad (36)$$

If the value of "E" obtained by solving the above equation is of such magnitude that it will not effect the desired accuracy, then accept ${}_2(\rho o)_n$ as the correct value of the oil saturation. It is necessary to solve equation 2 for the value of the slope ${}_2\left(\frac{d\rho o}{d P}\right)_n$ corresponding to ${}_2(\rho o)_n$ and P_2.

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D. M. Bass is associate research technologist in the A and M College Division of the Texas Petroleum Research Committee. He has been primarily engaged in studying high pressure waterflooding recoveries from solution gas-drive reservoirs. A graduate of Louisiana State University with a BS degree in petroleum engineering, Bass was formerly with Magnolia Petroleum Company as a petroleum engineer.

Where:

$$\Psi = \frac{kg}{ko}\text{(psi, a function of saturation)} \quad . \quad . \quad . \quad (3a)$$

$$\lambda\,(p) = \frac{1}{\gamma\,\beta\,o}\,\frac{dS_o}{dP}\text{(lambda, a function of pressure)}$$

$$. \quad (3b)$$

$$\varepsilon\,(p) = \frac{1}{\gamma}\,\frac{d\,\gamma}{dP}\text{(epsilon, a function of pressure)} \quad . \quad (3c)$$

$$\eta\,(p) = \frac{\alpha}{\gamma\beta o^2}\,\frac{d\,\beta\,o}{dP}\text{(eta, a function of pressure)} \quad . \quad (3d)$$

$$\alpha\,(p) = \frac{\mu o}{\mu g}\,\gamma\,\beta\,o\text{ (alpha, a function of pressure)} \quad (3e)$$

In estimating reservoir performance, equation 1 is generally applied to the reservoir as a unit (without considering localized variations). Where sufficient data are available it may sometimes be applied, however, with a higher degree of accuracy, to a small segment of a reservoir, i.e., a lease. In the latter case anomalies of pressure and saturation can be taken into consideration, but caution should be exercised to insure that a proper drainage area is used for the lease. In large reservoirs it is a generally accepted practice to divide the reservoir into segments of similar characteristics and solve the equation for each segment individually.

Equation 1 shows that the change in reservoir oil saturation with pressure is equal to the sum of three terms divided by the sum of two terms. The right hand side of the equation has three terms $\gamma(p)$, ε (p) and $\eta(p)$, all of which are functions of reservoir pressure. The value of these functions must be known at each pressure in order to solve the equation. Means of securing the required data and its preparation for solving the equation are indicated below.

Methods of Solving Solution Gas Drive Equation

Laboratory and/or Field Data. In order to apply equation 1, it is normally required that the following information be obtained on the reservoir: The pore volume of the reservoir, the average initial reservoir pressure, and the volume per cent of oil, water, and gas in the pore volume. Since at the time most engineers are assigned to estimate the performance of a solution gas drive reservoir or lease, the reservoir is in intermediate stage of depletion, the following methods will show the data and procedure required in estimating the future production characteristics from any stage in the reservoir life.

Other reservoir and fluid properties required in making the calculations include:

Values of k_g/k_o as a function of oil saturation; in lieu of suitable field data it is suggested that laboratory data from respresentative core samples be used. Typical data are shown in Fig. 1.

Ratios of the viscosity of oil to gas as a function of pressure; this can perhaps be provided by laboratory data on the particular reservoir fluids. Such data are shown plotted in Fig. 2.

Solubility of the gas in the oil at various pressures up to reservoir pressure; shown in Fig. 3.

Density of the reservoir gas at various pressures up to reservoir pressure; shown in Fig. 4.

Formation volume factors of the oil at various pressures up to reservoir pressure, shown in Fig. 3.

The above data should be obtained at the reservoir temperature.

With the exception of the permeability and gas viscosity data, most of the other information is normally supplied in tabular and graphical form in standard fluid analyses from petroleum engineering laboratories.

Preparation of the Data. After the above data have been secured the remaining effort consists primarily in preparing the tables and graphs necessary in facilitating the calculations. The evaluation of the functions α, $\lambda(p)$, $\varepsilon(p)$ and $\eta(p)$ are particularly significant.

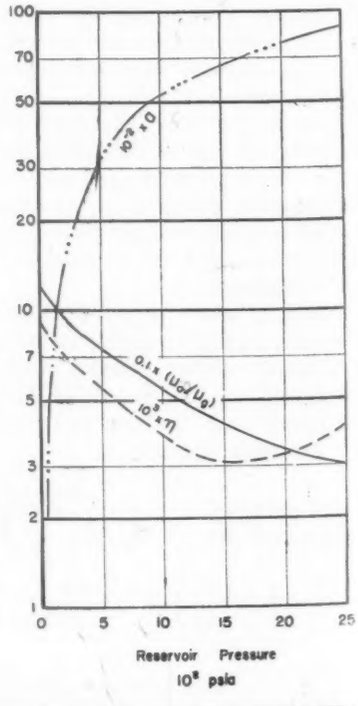
Evaluation of alpha, α(p)

Referring to equation (3) it will be seen that

$$\alpha = \gamma\,\beta\,o\,\frac{\mu o}{\mu g}$$

As each member of the term on the right hand side of the the equation is a function of pressure, it is suggested that three curves be plotted with pressure as abscissa (X-axis) and with γ, β_o and $\frac{\mu_o}{\mu_g}$ as the ordinates (Y-axis) respectively. A table, such as Table 1, is prepared with reservoir pressure as the first column, γ as the second column, β_o as the third column, $\frac{\mu_o}{\mu_g}$ as the fourth column, and α as the last column.

FIG. 2.



Figures 1 through 5 reproduced after Muskat "Physical Principles of Oil Production" (McGraw Hill—1949) page 412.

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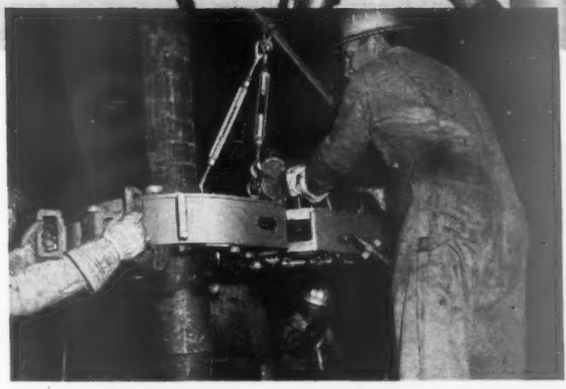

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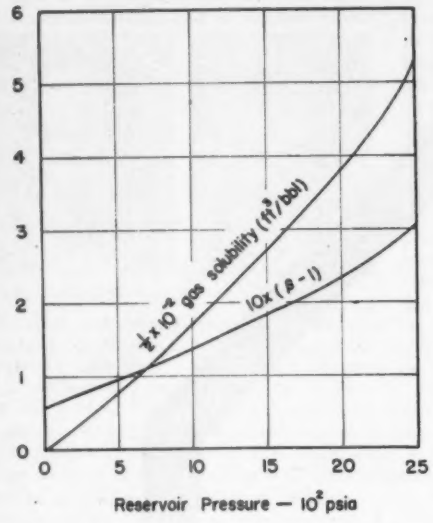

FIG. 3.

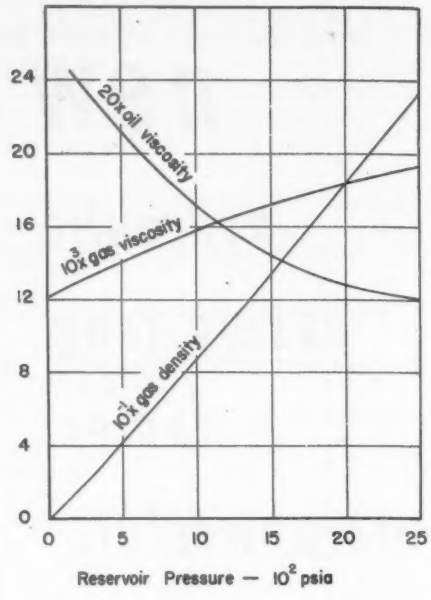

FIG. 4.

TABLE 1. Suggested table form for evaluating alpha.

P	γ	β_o	μ_o/μ_g	α
2500	236	1.308	30	9250
2250	215	1.265	31	8450
2000	187	1.235	34	7850
1750	168	1.207	36	7300
1500	139	1.185	41	6750
1250	112	1.161	46	6000
1000	87.1	1.137	53	5250
750	62.9	1.115	62	4350
500	41.8	1.098	73	3350
250	20.9	1.077	89	2000

Beginning with reservoir pressure or a convenient increment above reservoir pressure as the first entry in the pressure column, then proceed to form a diminishing arithmetic series using a convenient difference in pressure, such as 2500, 2250, 2000, etc. Using the 3 previously prepared graphs of γ, β_o and $\frac{\mu_o}{\mu_g}$ insert their proper values in the table opposite the column of pressures. Solve equation 3 for the proper values of α. Plot a curve of α versus pressure. This is shown in Fig. 2.

Evaluation of eta, η(p)

The term η(p) is given by:

$$\eta(p) = \frac{\alpha}{\gamma \beta o^2} \frac{d \beta_o}{dP}$$

A suggested procedure for evaluation eta, η(p), is indicated here. Prepare a table with columnar headings similar to Table 2.

In Table 2 column 1 represents the reservoir pressure and should be tabulated in a decreasing arithmetic series, i.e., with a constant increment: an increment of 250 psia is shown here. Column 2 represents the difference in successive pressure increments of column 1. The third column shows the values of β_o at various pressures. In the fourth column $\Delta\beta_o/\Delta P$ represents the difference between successive entries in column 3. Column 5 is obtained by dividing each entry in column 4 by the values in column 2. Column 6 represents the **average** pressure at which column 5 holds true.

TABLE 2. Suggested table form for evaluating Eta.

1 P	2 ΔP	3 β_o *	4 $\Delta\beta_o$	5 $\frac{\Delta\beta_o}{\Delta P}$	6 Pave	7 α	8 γ	9 β_o at Pave	10 η(P)×10^3
2625		1.3300							
2375	250	1.2855	0.0445	0.000178	2500	9250	236	1.308	0.410
2125	250	1.2477	0.0378	0.000151	2250	8450	215	1.265	0.370
1875	250	1.2177	0.0300	0.000120	2000	7850	187	1.235	0.330
1625	250	1.1917	0.0260	0.000104	1750	7300	168	1.207	0.310
1375	250	1.1692	0.0225	0.0000899	1500	6750	139	1.185	0.310
1125	250	1.1487	0.0205	0.0000820	1250	6000	112	1.161	0.325
875	250	1.1285	0.0202	0.0000809	1000	5250	87.1	1.137	0.375
625	250	1.1083	0.0202	0.0000809	750	4350	62.9	1.115	0.450
375	250	1.088	0.0203	0.0000812	500	3350	41.8	1.098	0.540
125	250	1.0680	0.0200	0.0000800	250	2000	20.9	1.077	0.660

*For $\Delta\beta_o$ to be accurate to three digits it is necessary that β_o be plotted so that it can be read to the accuracy shown.

Pressure values in column 6 are equal to those in column 1 minus ½ Δ P. Columns 7, 8, and 9 represent the values of α, γ, and β_o at the pressures shown in column 6. To compute eta, η(p), multiply the ratio in column 5 by the term in column 7, divide by the term in column 8 and the square of the term in column 9. After obtaining η(p), column 10 a graph should be prepared of η versus pressure values from columns 10 and 6 respectively.

Evaluation of Lambda, λ(p)

The following expression represents λ(p):

$$\lambda(p) = \frac{dSo}{\lambda \beta_o \, dP}$$

The value of λ may be determined by a similar procedure as that described for η. A suggested tabular form to aid in the calculation is shown in Table 3.

TABLE 3. Suggested table form for evaluating lambda.

1 P	2 ΔP	3 S_o	4 ΔS_o	5 $[\Delta S_o/5.61\Delta P]$ *	6 Pave	7 γ	8 β_o	9 λ(P)×10^3
2625		1160.6						
2375	250	979.6	191	0.136	2500	236	1.308	0.440
2125	250	831.6	148	0.105	2250	215	1.265	0.385
1875	250	708.6	123	0.0877	2000	187	1.235	0.380
1625	250	593.1	115.5	0.0832	1750	168	1.207	0.410
1375	250	486.6	106.5	0.0758	1500	139	1.185	0.460
1125	250	387.9	98.7	0.0703	1250	112	1.161	0.54
875	250	294.8	93.1	0.0664	1000	87.1	1.137	0.67
625	250	208.3	86.5	0.0616	750	62.9	1.115	0.88
375	250	121.3	87.0	0.0620	500	41.8	1.098	1.35
125	250	31	90.3	0.0642	250	20.9	1.077	2.85

* The constant 5.61 converts from cu ft/bbl to cu ft/cu ft.

It should be pointed out that columns 7 and 8 (Table 3) should be the values occurring at the pressures shown in column 6. Column 9 should be plotted versus column 6. This is shown in Fig. 5.

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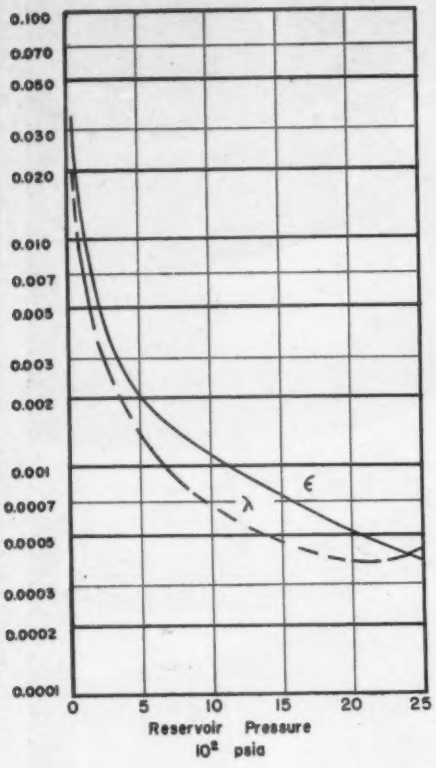


FIG. 5.

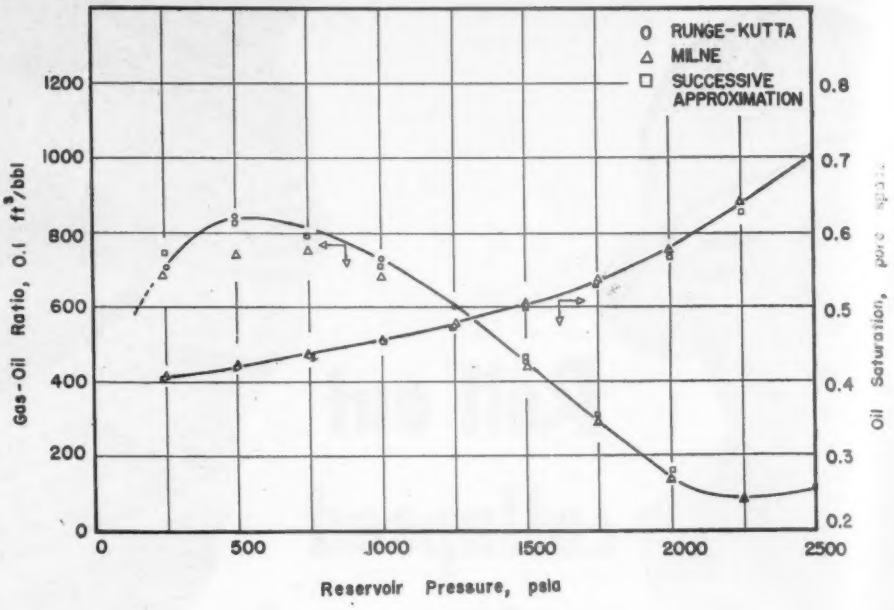


FIG. 6.

Evaluation of epsilon, $\varepsilon(p)$

The value of $\varepsilon(p)$ is given by the following relation:

$$\varepsilon(p) = \frac{1}{\gamma}\,\frac{d\gamma}{dP}$$

The above may be evaluated by a similar procedure as that described for $\eta(p)$. A suggested table to aid in the calculation is shown below as Table 4.

TABLE 4. Suggested table form for evaluating epsilon.

1 P	2 ΔP	3 γ	4 Δγ	5 Δγ/ΔP	6 Pave	7 γ	8 1/γ	9 ε(ρ)×10³
2625		245.0						
2375	250	223.2	21.8	0.0874	2500	236	0.00424	0.370
2125	250	200.1	23.1	0.0925	2250	215	0.00465	0.430
1875	250	176.3	23.8	0.0954	2000	187	0.00535	0.510
1625	250	150.3	26.0	0.1042	1750	168	0.00595	0.620
1375	250	124.3	26.0	0.1042	1500	139	0.00720	0.750
1125	250	99.1	25.2	0.1009	1250	112	0.00893	0.900
875	250	75.2	23.9	0.0958	1000	87.1	0.01148	1.10
625	250	52.8	22.4	0.0893	750	62.9	0.0159	1.44
375	250	31.4	21.4	0.0857	500	41.8	0.0239	2.05
125	250	10.5	21.9	0.0878	250	20.9	0.0479	4.20

Column 7 (Table 4), should show the values γ occurring at the pressures shown in column 6. A plot should be made of column 6 versus column 9. This is shown in Fig. 5.

The solution gas drive equation 2 may be solved by several methods, and it is a purpose of this paper to describe and compare three of these methods.* All of the methods presented here represent approximate solutions; however, the degree of accuracy of these methods is probably greater than the reproducibility of core and fluid analysis data. Any one of the methods described here may be applied to a reservoir or lease in a fairly short time.

The methods which are presented here for solving the solution gas drive equation are not new. They were originally presented in the literature some 50 years ago.[1,2,3,5] In realization that the reservoir engineer may not have the time nor opportunity to find and review these methods, this paper has been prepared to illustrate these published means of solving Muskat's solution gas drive equation.

*Muskat suggested the use of the Milne and Runge-Kutta methods in solving the solution gas drive equation.

Method of Successive Approximations. Of the three methods presented here the method of successive approximations is perhaps the most universally known and used.[6] In its application it is necessary to have sufficient data at initial conditions with which the slope $\left(\frac{d\rho_o}{dP}\right)_1$ can be determined. After determining the initial slope and choosing the pressure increment (ΔP), successive values of oil saturation (ρ_o, rho) are obtained in the following manner:

For trial value of ρ_o at $P_2 = P_1 - \Delta P$

$$_1(\rho_o)_2{}^{**} = (\rho_o)_1 - \left(\frac{d\rho o}{dP}\right)_1 \Delta P \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Solve equation 2 for $\frac{d\rho_o}{dP}$ using values $\eta(p)$, $\varepsilon(p)$, $\lambda(p)$, $\Psi(\rho_o)$ and μ_o/μ_g as determined by $(P)_2$ and $_1(\rho_o)_2$. Using the new value of the slope $\left(\frac{d\rho_o}{dP}\right)_2$ determine the second trial value of the oil saturation $_2(\rho o)_2$ as follows:

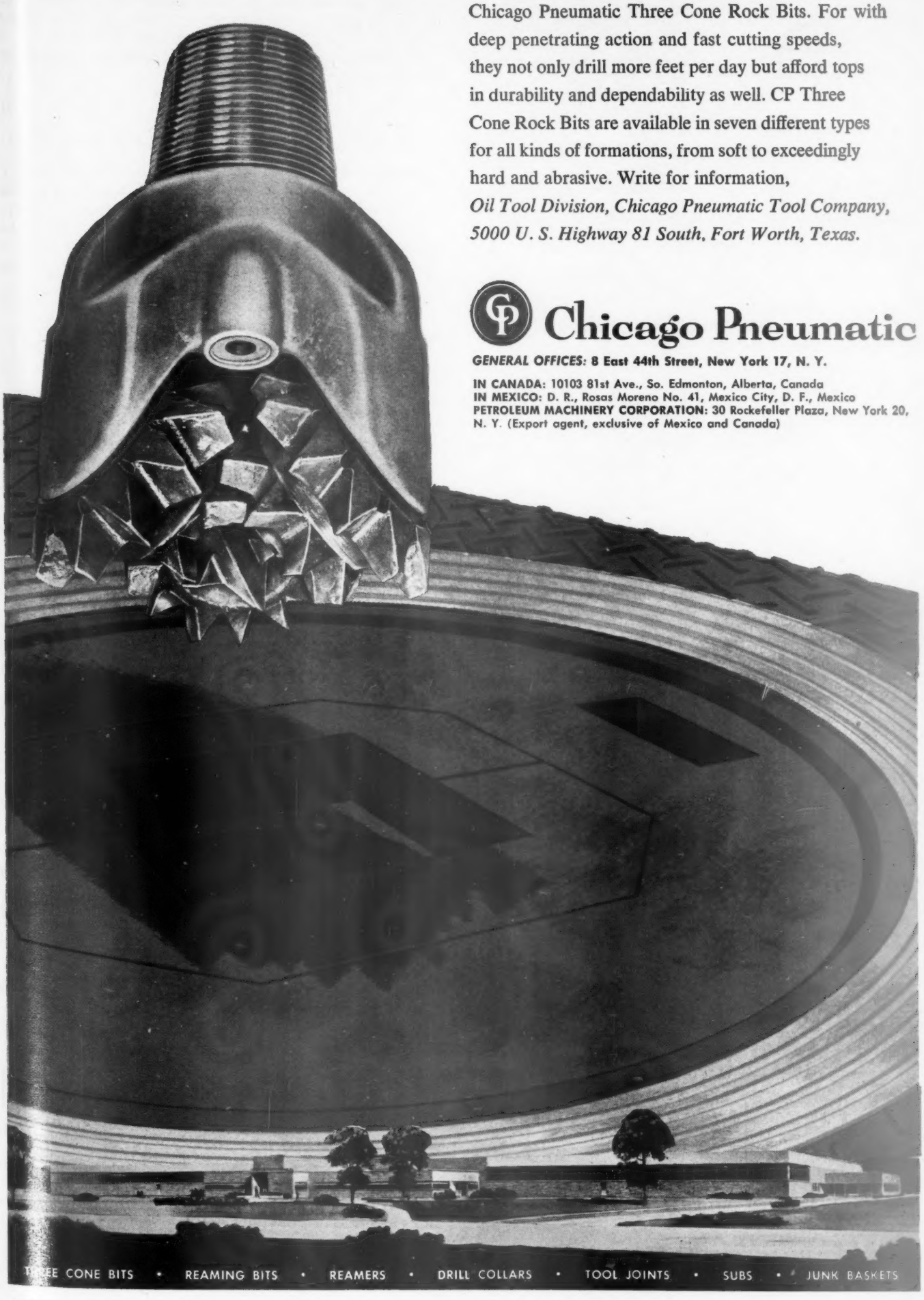
$$_2(\rho o)_2 = (\rho o)_1 - \left[\frac{\left(\frac{d\rho o}{dP}\right)_1 + {}_1\left(\frac{d\rho o}{dP}\right)_2}{2}\right]\Delta P. \quad (5)$$

Solve equation 2 using pertinent values corresponding to the oil saturation $_2(\rho o)_2$ and obtain the value of the new slope $_2\left(\frac{d\rho o}{dP}\right)_2$ at $_2(\rho_o)_2$. Solve equation 6

$$_3(\rho o)_2 = (\rho_o)_1 - \left[\left(\frac{d\rho o}{dP}\right)_1 + {}_2\left(\frac{{}^{o}dp}{dP}\right)_2\right]\frac{\Delta P}{2}. \quad (6)$$

for a new value of the oil saturation at P_2. This procedure is continued until the values of $_{n-1}(\rho o)_2$ and $_n(\rho o)_2$ are identical to the desired number of significant figures.

**$_1(\ )_2$ The subscript on the right of the parenthesis represents the point being solved for; the subscript on the left represents the sequence of trial values used to determine the correct value.



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A sample calculation of this method follows:

$(\rho o)_1 = 0.700$

$P_1 = 2500$ psia

$$\left(\frac{d\,\rho o}{d\,P}\right)_1 = \frac{\lambda\,(p)\,\rho o + (1 - \rho o - \rho w)\,\varepsilon\,(p) + \eta\,(p)\,\rho o\,\Psi}{\left(1 + \frac{\mu g}{\mu o}\,\Psi\right)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$\left(\frac{d\,\rho o}{d\,P}\right)_1 = \frac{(0.00044)\,0.7 + (1 - 0.7 - 0.3)0.00037 + (0.0041)\,(0.7)\,(0)}{1 + (30)\,(0.0)}$$

$$= 0.000308$$

with $\Delta P = 250$ psi

$${}_1(\rho_o)_2 = 0.7 - (0.000308)\,250 = 0.623 \text{ (first trial)}$$

with $\rho o = 0.623$ and $P = 2250$

$${}_1\left(\frac{d\,\rho o}{d\,P}\right)_2 = \frac{(0.000385)\,0.623 + (1 - 0.623 - .3) \times (0.00043) + (0.0037)\,(0.623)\,(0)}{1 + (31)\,(0.0)}$$

$$= 0.000273$$

Then

$${}_2(\rho o)_2 = 0.7 - \left[\frac{0.000308 + 0.000273}{2}\right] 250$$

$$= 0.6275 \text{ (second trial)}$$

Then

$${}_2\left(\frac{d\,\rho o}{d\,P}\right)_2 = \frac{(0.000385)\,0.6275 + (1 - 0.6275 - 0.3) \times (0.00043) + (0.0037)\,(0.6275)\,(0)}{1 + 31\,(0)}$$

$$= 0.000273$$

Then

$${}_3(\rho o)_2 = 0.7 - \frac{0.000308 + 0.000273}{2} \times (250)$$

$$= 0.6275 \text{ (third trial)}$$

As ${}_2(\rho o)_2$ and ${}_3(\rho o)_2$ are identical through the first 4 digits, 0.6275 can be used as the oil saturation at a reservoir pressure of 2250 psia.

The same procedure is followed in solving for the oil saturation at the next lower reservoir pressure, that is where

$$P_3 = P_1 - 2\,\Delta P = P_2 - \Delta P \quad \ldots\ldots\ldots (7)$$

Then

$${}_1(\rho o)_3 = {}_3(\rho o)_2 - \left(\frac{d\,\rho o}{d\,P}\right)_2 \Delta P \ldots\ldots (8)$$

$${}_2(\rho o)_3 = {}_3(\rho o)_2 - \left[\frac{\left(\frac{d\rho o}{d\,P}\right)_2 + \left(\frac{d\rho o}{d\,P}\right)_3}{2}\right] \Delta P \quad (9)$$

$${}_3(\rho o)_3 = {}_3(\rho o)_2 - \left[\left(\frac{d\rho o}{d\,P}\right)_2 + \left(\frac{d\rho o}{d\,P}\right)_3\right] \frac{\Delta P}{2}$$

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

The values of the slopes are obtained in each case by solving equation 2. This procedure is continued stepwise for each successive pressure until the oil saturation at the lowest pressure of interest has been computed. The calculated results are given in Table 5 and presented graphically in Fig. 6.

The gas-oil ratios may be readily computed by equation 2 for each pressure of interest.

$$R = [S_o + \propto \Psi]\,5.61 \quad \ldots\ldots\ldots\ldots\ldots (2a)$$

$$= [189.9 + (9250)\,(0)]\,5.61$$

$$= 1065 \text{ cu ft/bbl}$$

Runge-Kutta Method. The Runge-Kutta is one of the older method of numerical integration.[2, 5, 6] It is more laborious than the other methods presented here but is believed to give a higher degree of accuracy than the method of successive approximations. In using this method it is necessary to solve equation 2 using the initial values ε, η, λ, etc. to obtain a value of the slope $\left(\frac{d\rho o}{d\,P}\right)_1$. The value of the oil saturation at P_2 is obtained in the following manner:

$$\text{let } (\Delta\,\rho o)_1 = \left(\frac{d\rho o}{d\,P}\right)_1 \Delta P \ldots\ldots\ldots (11)$$

Solve equation (2) using

$$\rho o = (\rho o)_1 - \left(\frac{\Delta\,\rho o}{2}\right)_1 \ldots\ldots\ldots (12)$$

$$\text{for } P = P_1 - \frac{\Delta P}{2} \ldots\ldots\ldots (13)$$

Obtaining a new slope ${}_1\left(\frac{d\rho o}{d\,P}\right)_2$

$$\text{let } (\Delta\,\rho o)_2 = {}_1\left(\frac{d\rho o}{d\,P}\right)_2 \Delta P \ldots\ldots\ldots (14)$$

and again solve equation (2) using $\rho o = (\rho o)_1 - \left(\frac{\Delta\,\rho o}{2}\right)_2$

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots (15)$$

$$\text{for } P = P_1 - \frac{\Delta P}{2} \ldots\ldots\ldots (13)$$

Obtaining another value for the slope ${}_2\left(\frac{d\rho o}{d\,P}\right)_2$

$$\text{let } (\rho o)_3 = {}_2\left(\frac{d\rho o}{d\,P}\right)_2 \Delta P \ldots\ldots\ldots (16)$$

and solve equation (2) using

$$\rho o = (\rho o)_1 - (\Delta\,\rho o)_3 \ldots\ldots\ldots (17)$$

$$\text{for } P = P_1 - \Delta P \ldots\ldots\ldots (18)$$

Obtaining ${}_3\left(\frac{d\rho o}{d\,P}\right)_2$

$$\text{Let } (\Delta\rho o)_4 = {}_3\left(\frac{d\rho o}{d\,P}\right)_2 \Delta P \ldots\ldots (19)$$

and solve the following equation for the value of the oil saturation at P_2.

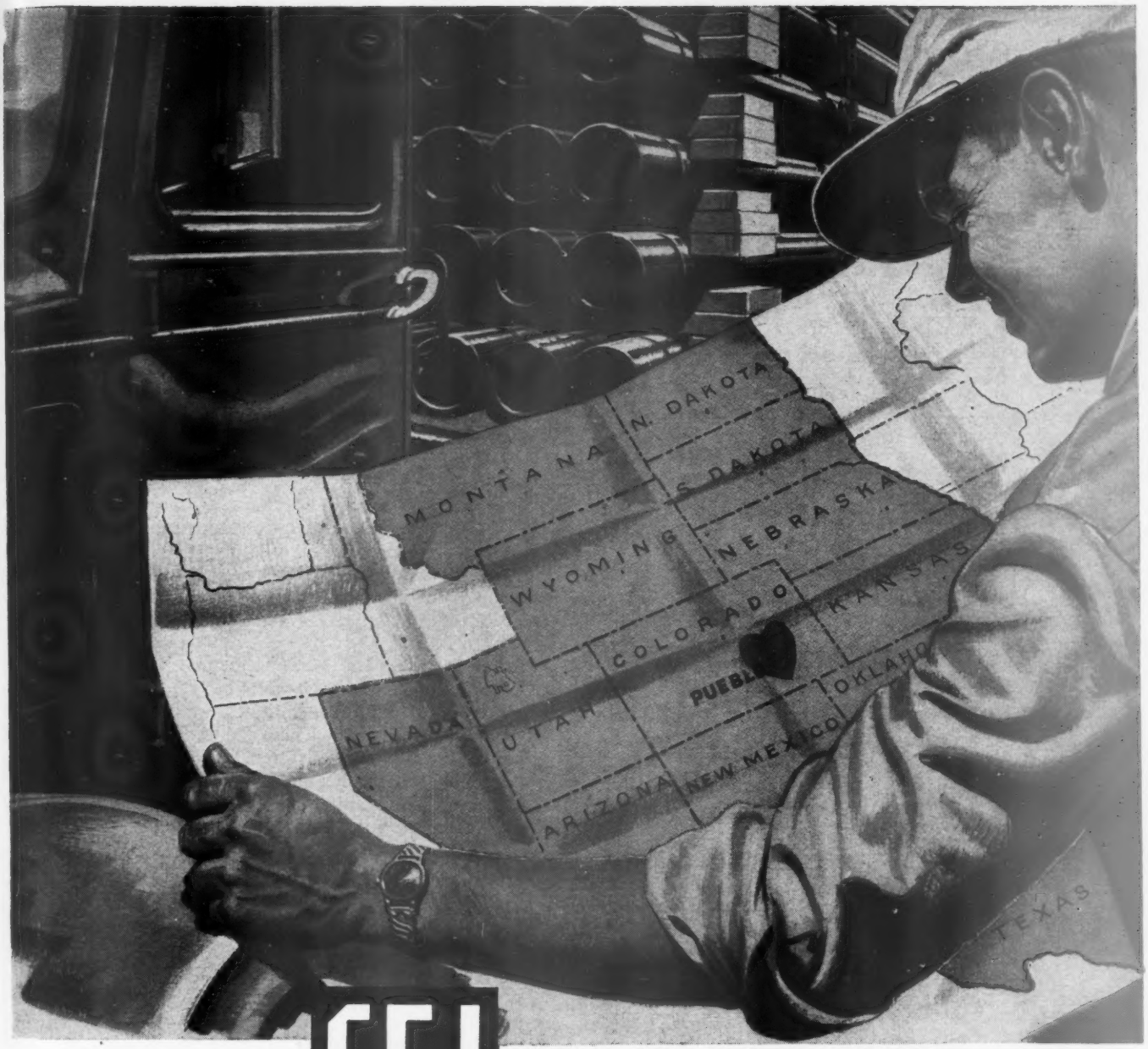
$$(\rho o)_2 = (\rho o)_1 - \frac{1}{6}\left[(\Delta\rho o)_1 + 2(\Delta\rho o)_2 + 2(\Delta\rho o)_3 + (\Delta\rho o)_4\right]$$

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots (20)$$

$$P_2 = P_1 - \Delta P \ldots\ldots\ldots (18)$$

After determining the value of $(\rho o)_2$ at P_2, solve for $(\rho o)_3$ at P_3 by the same procedure as above: that is

$$(\Delta\,\rho o)_1 = \left[{}_4\left(\frac{d\rho o}{d\,P}\right)_2\right] \Delta P \ldots\ldots\ldots (21)$$



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then

$$(\Delta\rho o)_2 = \left[\ {}_1\left(\frac{d\rho o}{dP}\right)_2 \ \right]\Delta P \quad \ldots \quad (22)$$

Where

$$\rho o = (\rho o)_2 - \frac{(\Delta \rho o)_1}{2} \quad \ldots \quad (23)$$

$$P = P_2 - \frac{\Delta P}{2} \quad \ldots \quad (24)$$

Then

$$(\Delta\rho o)_3 = \left[\ {}_2\left(\frac{d\rho o}{dP}\right)_3 \ \right]\Delta P \quad \ldots \quad (25)$$

Where

$$\rho o = (\rho o)_2 - \frac{(\Delta \rho o)_2}{2} \quad \ldots \quad (26)$$

$$P = P_2 - \frac{\Delta P}{2} \quad \ldots \quad (24)$$

Then

$$(\Delta\rho o)_4 = \left[\ {}_3\left(\frac{d\rho o}{dP}\right)_3 \ \right]\Delta P \quad \ldots \quad (27)$$

Where

$$\rho o = (\rho o)_2 - (\Delta\rho o)_3 \quad \ldots \quad (28)$$

$$P = P_2 - \Delta P \quad \ldots \quad (29)$$

$$\text{then } (\rho o)_3 = (\rho o)_2 - 1/6\,[(\Delta\rho o)_1 + 2(\Delta\rho o)_2 + 2(\Delta\rho o)_3 + (\Delta\rho o)_4] \quad \ldots \quad (30)$$

$$P_3 = P_2 - \Delta P \quad \ldots \quad (31)$$

An illustration follows:

$P_1 = 2500$ psia $\quad (\rho o)_1 = 0.7 \quad \rho w = C = 0.3$

$\left(\frac{d\rho o}{dP}\right)_1 = .000308$ as determined in the previous example.

$(\Delta\rho o)_1 = (.000308)\,(250) = .077$

$$\rho o = .7 - \frac{.077}{2} = .6615 \qquad P = 2500 - \frac{250}{2} = 2325$$

Solve equation 2 with the above values

$$ {}_1\left(\frac{d\rho o}{dP}\right)_2 = \frac{[(0.0004)\,(0.6615) + (1 - 0.6615 - 0.3)\,0.0004 + (0.0039) \times (0.6615)\,(0)]}{[1 + (30.5)\,(0)]}$$

$$ {}_1\left(\frac{d\rho o}{dP}\right)_2 = 0.00021$$

$$(\Delta\rho o)_2 = {}_1\left(\frac{d\rho o}{dP}\right)_2 \Delta P = (.00021)\,(250) = 0.0525$$

$$\rho o = 0.7 - \frac{.0525}{2} = 0.6727 \qquad P = 2500\text{-}250/2 = 2325$$

$$ {}_2\left(\frac{d\rho o}{dP}\right)_2 = [(0.0004)\,(0.6727) + (1 - 0.6727 - 0.3) \times (0.0004) + (0.0093)\,0.6727\,(0)] \div [1 + 30.5\,(0)] = 0.00021$$

for which

$$(\Delta\rho o)_3 = {}_3\left(\frac{d\rho o}{dP}\right)_2 \Delta P = (0.00021)\,(250) = 0.0525$$

$$\rho o = 0.7 - 0.0525 = 0.6475 \qquad P = 2500 - 250 = 2250$$

Using the above values of ρo and P

Then

$$ {}_3\left(\frac{d\rho o}{dP}\right)_2 = [(0.000385)\,(0.6475) + (1 - 0.6475 - 0.3)\,0.00043 + 0.0037 \times (0.6475)\,(0)] \div [1 + (31)\,(0)] = 0.000272$$

for which

$$(\Delta\rho o)_4 = {}_3\left(\frac{d\rho o}{dP}\right)_2 \Delta P = (0.000272)\,(250) = 0.068$$

The oil saturation $(\rho o)_2$ at a reservoir pressure of 2250 psia is given by:

$$(\rho o)_2 = (\rho o)_1 - \tfrac{1}{6}\,[(\Delta\rho o)_1 + 2(\Delta\rho o)_2 + 2(\Delta\rho o)_3 + (\Delta\rho o)_4] \quad \ldots \quad (20)$$

$$= 0.7 - \tfrac{1}{6}\,[0.077 + 2\,(0.0525) + 2\,(0.0525) + 0.068]$$

$$(\rho o)_2 = 0.6408$$

$$P_2 = P_1 - \Delta P = 2500 - 250 = 2250 \text{ psia}$$

It is necessary to solve equation 2 with the above values of the oil saturation and reservoir pressure in order to determine the value of $(\Delta\rho o)_1$ used in obtaining the oil saturation at a reservoir pressure of 2000 psia. The remaining $(\Delta\rho o)$ values are obtained in the same manner as above except 0.6408 is used for (ρo) in place of 0.7 and 2250 is used for (P) in place of 2500.

Milne Method. The Milne[3,6] method of solving the type of equation under discussion requires that the first four values of the oil saturation at four pressure points be determined by some other method. These values may be obtained by either of the two methods already discussed or from data obtained by solving the material balance equation on past field history. To obtain points representing a state of further depletion it is necessary to solve the following equations.

$$ {}_1(\rho_o)_n = (\rho_o)_{n-4} - \frac{4\Delta P}{3}\left[\ 2\left(\frac{d\rho_o}{dP}\right)_{n-1} - \left(\frac{d\rho_o}{dP}\right)_{n-2} + 2\left(\frac{d\rho_o}{dP}\right)_{n-3} \right] \quad \ldots \quad (32)$$

$$P_n = P_1 - [(n-1)\,\Delta P] \quad \ldots \quad (33)$$

Solve equation 2 using the above determined values of (ρo) and (P) and obtain a value for the slope at P_n of $ {}_1\left(\frac{d\rho o}{dP}\right)_n$. Using the value of the slope solve the following equation for another value of $(\rho_o)_n$.

$$ {}_2(\rho o)_n = (\rho_o)_{n-2} - \frac{\Delta P}{3} \times \left[\ {}_1\left(\frac{d\rho o}{dP}\right)_n + 4\left(\frac{d\rho o}{dP}\right)_{n-1} + \left(\frac{d\rho o}{dP}\right)_{n-2} \right] \quad \ldots \quad (34)$$

$$P_n = P_1 - [\,(n-1)\,\Delta P\,] \quad \ldots \quad (35)$$

An equation, developed by Milne, for determining the error of this method is:

$$E = \left[\frac{ {}_2(\rho o)_n - {}_1(\rho o)_n}{29} \right] \quad \ldots \quad (36)$$

If the value of "E" obtained by solving the above equation is of such magnitude that it will not effect the desired accuracy, then accept $ {}_2(\rho o)_n$ as the correct value of the oil saturation. It is necessary to solve equation 2 for the value of the slope $ {}_2\left(\frac{d\rho o}{dP}\right)_n$ corresponding to $ {}_2(\rho o)_n$ and P_2.

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For illustrative purposes a sample calculation follows:

Point	Pressure	Δ P	ρo	$\frac{d\rho o}{dP}$
1	2500		0.7	0.000308
2	2250	250	0.641	0.000272
3	2000	250	0.526	0.000218
4	1750	250	0.532	0.000138
5	1500	250	to be determined	

With the first four values, listed above, being determined by the Runge-Kutta method it is then possible to solve equation 32.

Where n = 5

$$ {}_1(\rho o)_5 = (\rho o)_1 - \frac{4\Delta P}{3} \times \left[2\left(\frac{d\rho o}{dP}\right)_4 - \left(\frac{d\rho o}{dP}\right)_3 + 2\left(\frac{d\rho o}{dP}\right)_2 \right] $$

$$ = 0.70 - \frac{4(250)}{3}[2(0.000138) - 0.000218 + 2(0.000272)] $$

$$ = 0.499 $$

$P_5 = 2500 - 4(250) = 1500$ psia

Solving equation (2) with $\rho o = 0.499$ and $P = 1500$ psia

$$ {}_1\left(\frac{d\rho o}{dP}\right)_5 = $$

$$ [(0.00046)(0.499) + (1 - 0.499 - 0.3)(0.00075) + (0.0031) \times (0.499)(0.103)] \div [1 + 41(0.103)] = 0.0001034 $$

Then

$$ {}_2(\rho o)_5 = (\rho o)_3 - \frac{\Delta P}{3} \left[{}_1\left(\frac{d\rho o}{dP}\right)_5 + 4\left(\frac{d\rho o}{dP}\right)_4 + \left(\frac{d\rho o}{dP}\right)_3 \right] $$

$$ = 0.576 - \frac{250}{3} \times $$

$$ [(0.0001034) + 4(0.0001382) + 0.0002182] $$

$$ = 0.503 $$

The error is: $E = \left| \frac{0.503 - 0.499}{29} \right| = 0.0001$

As only three significant figures are being used, a value of .0001 will not alter the answer. Solve equation 2 with the above values:

$$ \left(\frac{d\rho o}{dP}\right)_5 = $$

$$ [(0.00046)(0.503) + (1 - 0.503 - 0.3)(0.00075) + (0.0031) \times (0.503)(0.100) \div [1 + 41(0.100)] = 0.0001049 $$

It is only necessary to repeat the above procedure using n = 6, 7, 8, etc., to determine the remaining values of ρo and P.

The gas-oil ratio at 1500 psia is given by equation (2a) or:

$$ R = [S_o + \propto \Psi] 5.61 \quad \ldots\ldots\ldots\ldots \quad (2a) $$

$$ = [97.0 + (6750)(0.10)] 5.61 $$

$$ = 4340 \text{ cu ft/bbl} $$

Discussion and Comparisons of Results

Fig. 6 and Table 5 were prepared so that detailed comparisons could be made of the three integrating procedures described here. Referring to Table 5 it may be seen that the computed oil saturations obtained by the 3 methods differ by less than 0.02 pore volumes during the intermediate stages of production and by only 0.001 pore volumes at 250 psia.

Referring to Fig 6 and Table 5 it is seen that the 3 integrating methods may be expected to give only fair agreement when calculating the gas-oil ratios. In the illustration presented it will be noted that the method of successive approximations and Runge-Kutta method give the highest gas-oil ratios. This occurs at 500 psia where the gas-oil ratio is 8305 cut ft per barrel. The Milne method gives a gas-oil ratio of 7725 cu ft per barrel at 500 psia.

All three methods described here may be applied to estimate the performance of a solution gas drive reservoir or segment thereof, but each method has certain characteristics which make it desirable in some instances.

The first method, called the method of successive approximations, may be used to calculate an entire performance curve using variable pressure increments. It is easiest to apply when the variation of saturation with pressure is small.

The Runge-Kutta method is a fairly fast and accurate method and will be found useful in many instances. The error in the method is approximately the same as that of Simpson's rule. If a more accurate answer is desired, closer pressure increments may be chosen which will reduce the error. A distinct advantage in the Runge-Kutta method is the ability to use pressure increments of various sizes in solving the same problem.

The Milne method is easier and faster to apply than the Runge-Kutta method, and the calculated oil saturations are approximately the same. The gas-oil ratios vary somewhat, but the oil saturations are identical with the Runge-Kutta method for the first two digits. The Milne method cannot be used to obtain the first four data points, but after these are obtained it is the fastest and easiest to apply. It should be pointed out, however, that the pressure increments cannot be changed once a series of calculations are started.

A suggested procedure to follow in solving the solution gas drive equation is to use the Runge-Kutta method to solve for the first four data points and to use the Milne method to complete the solution. Such a procedure, if followed, permits the calculations to be made with both speed and accuracy. The Milne method is perhaps the fastest method and the calculated performance curves will generally be sufficiently accurate if ten uniform pressure increments are taken. In case the reproducibility of the reservoir data warrants a more accurate calculation, a greater number of increments may be used.

TABLE 5. Comparisons of three methods of estimating solution gas drive performance.

	Successive approximation			Runge-Kutta			Milne		
Pressure psia	ρo sat'n	dρo/dP x10⁶	R cu ft/bbl	ρo sat'n	dρo/dP x10⁶	R cu ft/bbl	ρo sat'n	dρo/dP x10⁶	R cu ft/bbl
2500	0.700	308	1065	0.700	308.0	1065	0.700	308.0	1065
2250	0.628	273	885	0.641	272.2	885	0.641	272.2	885
2000	0.568	200	1555	0.575	218.2	1332	0.575	218.2	1332
1750	0.527	131	3225	0.532	138.2	2850	0.532	138.2	2850
1500	0.499	99.5	4755	0.502	103.4	4445	0.503	104.9	4340
1250	0.476	84.3	5860	0.474	82.6	6070	0.479	86.8	5560
1000	0.456	73.5	7070	0.455	72.8	7280	0.459	75.5	6780
750	0.438	72.5	7900	0.438	64.1	7895	0.440	69.3	7565
500	0.421	64.2	8305	0.421	65.0	8305	0.424	69.1	7725
250	0.404	69.7	7400	0.404	71.4	7025	0.405	73.1	6910

Acknowledgment

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Interpretation Problems In RADIOACTIVITY LOGGING

James H. Russell

OBSERVER checks intensity of radioactivity eminations on the recorded log being made at left. Nerve center of the system is an integrator panel at upper left of this instrument stack. Collar locator panel is immediately below the integrator panel.

VARIATIONS in behavior of radioactivity logs from one area to another have been resolved in many cases by increased application and constant analysis of the problems involved in interpretation. In the Frio section of South Texas, for example, there was an apparent lack of correlation between the gamma ray curve and the self-potential of the electrical log. Why does this exist? Careful study showed that volcanic ash, prevalent in the Frio, is highly radio active, relatively speaking. It produces anomalies of equal or higher strength than adjacent shales. When this phenomenon came to light, the problem of interpretation was greatly simplified.

As another example, experience and study revealed that the shale-sand concept normally used in the Gulf Coast area did not apply to that part of the Wilcox which is classified as continental rather than marine in origin. In these areas, there is no sharp definition between sands and clay materials. Highly mineralized areas in thick sandstone bodies complicate the definition of a gamma ray log. Even electrical logs do not behave in the generally accepted manner. Also, anomalies associated with lignite beds depart radically from conventional anomalies ordinarily signifying sands and shales in both radiation and electrical logging. This knowledge has aided materially in explaining radioactivity logging behavior in these areas.

South Louisiana provides still another example, for there it is possible in some fields to pick the water-oil contact in the producing horizon, while other areas have shown no evidence of anomalies. This phenomenon was unveiled when the produced formation water was analyzed. It was found to contain potassium, one of the naturally radioactive elements that produce anomalies on the gamma ray curve. Such are the peculiarities revealed by increased application and constant study.

As the use of gamma ray logs has become more widespread, it is of considerable interest to note the many different approaches to interpretation that are necessary in the various geological areas. The original concept of a gamma ray log has been altered substantially to meet the needs of the particular area in which it is run. For the greater part of the Gulf Coast area, the conventional interpretation still serves quite well. This, of course, is based on the fact that in general shales are more radioactive than sands or limestones. The resulting log is therefore quite correlatable with the self-potential and resistivity curves of the electrical log.

But as the gamma ray log becomes more widespread in its use, new and interesting departures from the original interpretations are necessary. For instance, in certain areas of the southwest part of the Gulf Coastal plains, gamma ray logs were run that completely baffled those who were interested in their interpretation. Subse-

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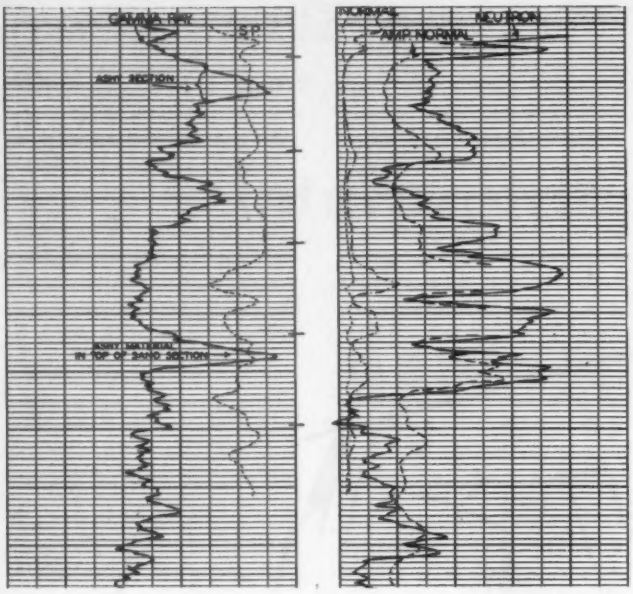


FIG. 1. Typical comparison of a radiation log and an electrical log in the ashy section of the Frio formations in South Texas.

quent study on this problem brought to light important facts and information that enables these logs to be correctly interpreted today. These revelations added greatly to the value of logs in hands of capable petroleum geologists.

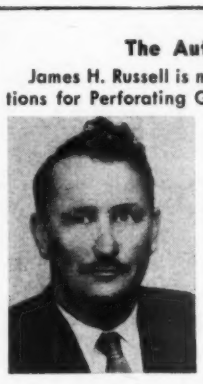
As the storehouse of knowledge concerning gamma ray logs increased, an additional curve was added as a companion to the gamma ray. This was the neutron log. Many papers concerning the basic theory of both gamma ray and neutron logs have been written. They have offered a fertile field for the highly technical man to expound complex mathematical formulae on the theories of probability, statistical variation, wave radiation, particle radiation, and many others too numerous to mention.

Trying to reconcile all of these complicated dissertations to the every-day job of running gamma ray and neutron logs has sometimes left the whole thing somewhat fuzzy in many minds. But it must be conceded that any tool, however perfect in theory and application, still derives its greatest value out of the resulting performance and experience data that is compiled as a result of its use. And the more complex the phenomena, the greater the importance of this data. The intended object of this paper is to bring together some of the performance and experience data, collected from several areas of application.

Fig. 1 is a typical example from the South Texas Frio section. It shows four curves of an electrical log superimposed over a radiation log consisting of a gamma ray curve and a neutron curve. It is interesting to note the lack of correlation between the gamma ray curve and the self-potential. This lack of graphic correlation is found principally in those areas producing from the Frio section of South Texas. Before the advent of neutron logging, the gamma ray log meant very little to the oil operator in these areas, since graphic correlation and subsequent measure corrections were the primary purposes of the use of the gamma ray log.

The Author

James H. Russell is manager of operations for Perforating Guns Atlas Corporation. His background consists of two years in geophysical research with Shell Petroleum Corporation, another two years as party chief of a geophysical exploration crew with Brown Geophysical Company, and two and one-half years in radiation logging with Lane-Wells Company. In 1944, he took a position as electrical development engineer with a company that was later merged with Perforating Guns Company which in turn, still later was merged with PGAC.



Russell first redesigned various electrical systems used on field service units. Next, he designed and supervised the building of all equipment for a radiation logging department and then he organized and managed that department for five years before being promoted to his present duties two years ago. He is a well-known author and lecturer on radioactive phenomena. He received his EE degree from Texas A. & I., and is a licensed Texas Professional Engineer. He is a member of API, Houston Geological Society, Houston Engineers Club, and the Texas Society of Professional Engineers.

Today, the gamma ray curve, run simultaneously with the neutron curve, tells much more. It is immediately apparent upon observation that excellent correlation is obtained between the neutron curve and the short normal and amplified normal. No doubt now exists regarding graphic correlation and any measure discrepancy that might exist between the two logs. In addition, the gamma ray, run simultaneously with the neutron, now tells information hitherto unavailable.

It is known today that the producing sands in the Frio section of the Southwest Gulf Coastal plains quite often are of an ashy or bentonitic nature. It is also known that this volcanic ash is highly radioactive, relatively speaking. In many cases the radioactive strength of the ash material within the sand body will give gamma ray anomalies of equal or higher strength than the adjacent shales, resulting quite often in complete lack of correlation between gamma ray and self-potential curves of the electrical log.

Further experience in producing these contaminated Frio sands has shown that those sands that are definitely known to bear oil—but which contain large quantities of ashy material—often fail to produce oil in commercial quantities. It has been determined that water from drilling muds causes such ashy material to swell, thereby greatly reducing the permeability of an otherwise porous sand.

The ability of a gamma ray curve to define the presence of ashy material has greatly aided in the completion in sands in these areas. It has become possible to select clean portions of the sand body for perforations, instead of those sections containing ashy contamination.

Following closely on the solution of this problem, another problem was encountered. Important field discoveries were being made in the Wilcox formation, adjacent to the Gulf Coastal plains. Here another perplexing problem concerning the interpretation of radiation logs was encountered. This trouble sprang primarily from the attempt to apply empirically the conventional interpretation derived from gamma ray and neutron logs run in the marine depositions of the Gulf Coastal plains. Virtually everyone concerned with this comparatively new Wilcox production already had considerable experience in using these logs in nearby areas and, naturally enough, expected similar results from the Wilcox. Subsequent study of this problem has revealed much interesting and valuable information for the storehouse of such knowledge.

With the advent of upper Wilcox

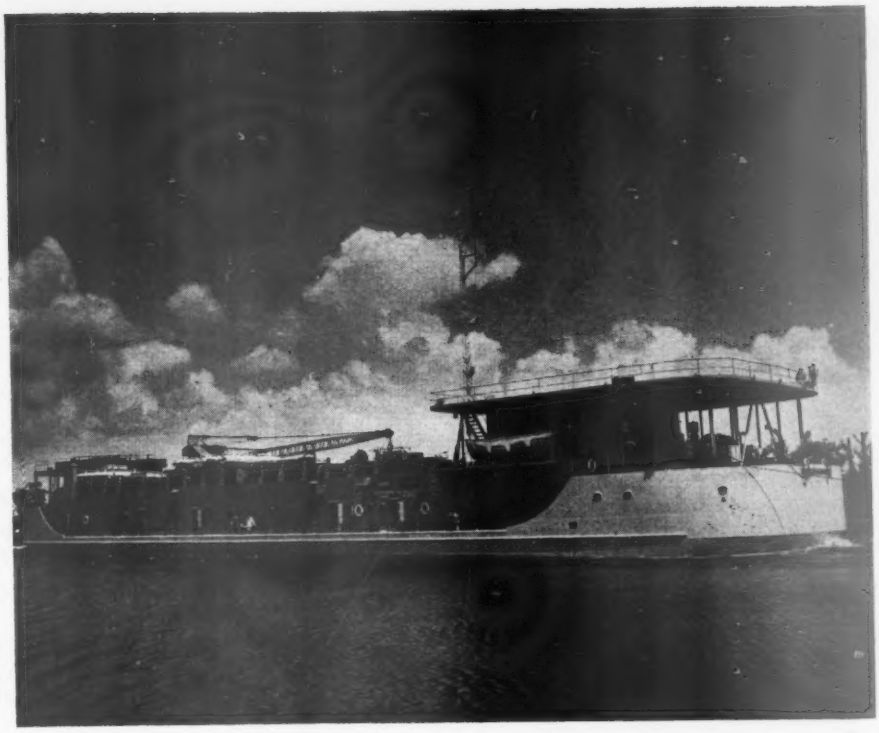
production, a new page is now added to the interpretation of radiation logs. It is found that the shale-sand concept is no longer true, particularly in those areas of production that have been classified as continental or non-marine formations. In these areas there are no clay materials. Highly mineralized sharp definitions between sands and areas in thick sandstone bodies complicate the definition of a gamma ray log. Lignite beds frequently encountered within the Wilcox do not have the classic relation to a shale bed as found in marine formations.

These differences also call for another approach to neutron interpretation. No longer can the neutron shifts from left to right be evaluated as going from shale to sand or limestone. We are confronted with huge thicknesses of strata predominantly silica, with various streaks of greater or lesser secondary mineralization, some being almost crystalline in nature. Interspersed with this are classic materials often permeating the entire strata.

To add to the confusion, even electrical logs do not behave in the generally accepted manner that we have come to view them in marine formations. Due to the high density, low porosity and, in many cases, the absence of saline fluids in the formation, we find that the so-called long normal curves of an electrical log greatly exceed the indicated resistivity values of the short normal curve.

This is a phenomenon encountered frequently in electrical logs run through the upper Wilcox. It is simply an indication of the relative electrical conductivity of the formations being measured. It implies that the conductivity of the bore hole fluid greatly exceeds that of the formation adjacent to the bore hole, thus bearing out the absence of saline fluids. It is further evidence of the basic differences between this part of the Wilcox formation and the great majority of other oil producing formations. This condition often extends through hundreds of feet of formation, some of which is productive.

Inter-bedded in an otherwise dense sandy formation, we have lignite beds. The anomalies associated with lignite beds in both radiation and electrical logs depart radically from the conventional anomalies ordinarily signifying sands and shales. These things occur commonly in sections of the upper Wilcox formation and cannot be interpreted from the basic, or text book, approach to log evaluation. They can be arrived at solely from a careful analysis of the problem at hand in conjunction with the record of performance data and experience compiled from wells in which this problem is confronted.



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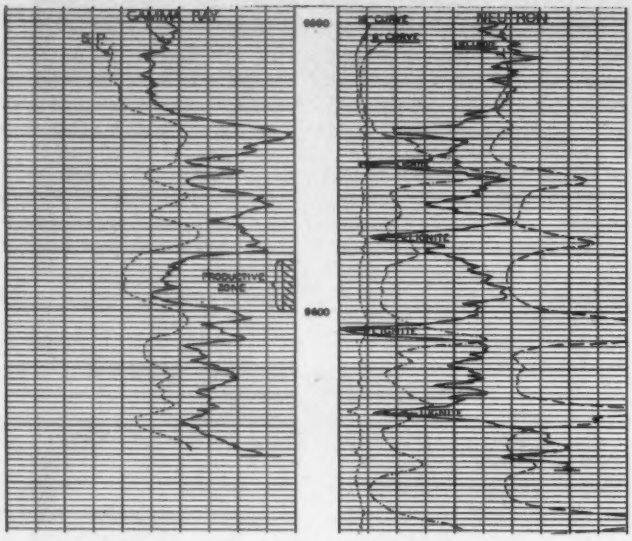

FIG. 2. Typical section of the Upper Wilcox gamma ray and neutron logs superimposed on the self-potential 18½-ft and 19½-ft resistivity curves taken in the New Ulm field of Austin County, Texas

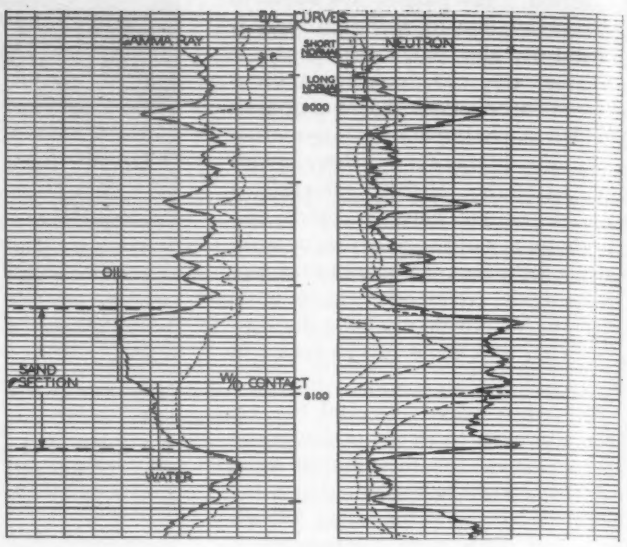

FIG. 3. Electrical log superimposed on a simultaneous radiation log of the pay section of a South Louisiana well. Due to radioactive potassium in the water, it was easy to pick the water-oil contact in the producing section

Fig. 2 shows a typical section of upper Wilcox gamma ray and neutron with the self-potential, 18 ft-6 in. and 19.5 ft resistivity curves super-imposed. It is interesting to note that there is considerable disagreement in the correlation of the self-potential and gamma ray curve. Most of this disagreement in the correlation lies in the different reaction between the two curves when logging through lignite beds. This self-potential apparently does not differentiate between lignite and the adjacent formation. On the other hand, the gamma ray does differentiate between them because of the difference in gamma ray emanations from these formations. Lignite apparently has a radioactive strength more nearly approaching that of the clastic materials than that of the sands.

The correlative differences between the neutron curve and the resistivity curves are even more striking. These lignite beds which are very thin apparently have very low conductivity and offer a very high degree of shielding to resistivity curves. On the other hand, again, since lignite beds are predominantly carbon, they offer considerable slowing-down effect to the neutron bombardment resulting in a pronounced minimum reading on the neutron curve. This minimum reading is unique from the standpoint of neutron interpretation in that it is a case where a low neutron reading *does not* indicate high porosity. It simply indicates that in this bed there are sufficient carbon atoms to make this curve respond exactly as it would in the presence of a high concentration of hydrogen, namely water or oil.

With further reference to Fig. 2, it is noted that production in this well was obtained in the section from 9582 to 9600 ft. There is very little on which to base the selection of this zone, from either the electrical or radiation log. But it is interesting to note that after we have excluded all of the lignite beds' effect from the neutron curve, this production is obtained from that section having a medium porosity—between that of the clastic materials and the really dense sections.

A study of gamma ray logs in South Louisiana also has brought forth some interesting interpretations. Notably among these is the fact that in some fields it is possible to pick the water/oil contact in the producing horizons. In some fields this anomaly is very clear-cut and is used consistently for the purpose of determining water/oil contacts. Other areas have shown no evidence of such anomalies. The fact that such anomalies were found in certain fields, and were not found in others, presented an intriguing problem, but the information gained from subsequent investigation has shed more light on the complex problem of utilizing all the information that a gamma ray log is capable of giving.

In reviewing the chemical analysis of salt water samples taken from many of the South Louisiana fields, an interesting fact came to light. The presence of potassium varied widely — from hardly noticeable traces in some fields, to amounts quite easily detectable in others. Potassium is one of the naturally radioactive elements and its presence in sufficient quantities in formation salt water produces a noticeable shift in the gamma ray log when going from that portion of the sand containing potassium-contaminated salt water to that portion containing oil.

Fig. 3 shows an excellent example of this condition. In this figure the self-potential and two shallow penetration resistivity curves of an electrical log are super-imposed over a simultaneous radiation log. It is interesting to note the high degree of correlation existing between the self-potential and gamma ray curves. In the sand section from 8071 to 8120 ft the oil/water information is indicated by the resistivity curves. It is apparent that the neutron does not differentiate between the two types of fluid known to be present in this sand body; however, upon observation of the gamma ray curve—and particularly after we understand the information it is conveying in this local area— we can immediately place the water/oil contact from the gamma ray curve alone.

The interpretation problems mentioned in this paper give but a very small idea of the many instances where a much more concentrated study is needed if we are to utilize all of the information that radiation logs are capable of furnishing. They are submitted also in an endeavor to point out the many misleading conclusions that may be reached when a purely empirical interpretation is attempted on radiation logs. * * *

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New Mexico Division For Continental Oil

Continental Oil Company has announced a New Mexico production division, with headquarters in Roswell. The area formerly was a part of Conoco's West Texas-New Mexico division, headquartered at Midland, Texas. R. L. Adams, assistant division superintendent at Midland, is superintendent of the new division.

Adams joined Conoco in 1946 as a roustabout in New Mexico. Before his promotion to assistant division superintendent at Midland in 1954, he served briefly as superintendent of Conoco's North Oklahoma production district. He received a BS in petroleum engineering from Texas A&M College.

Conoco operates approximately 500 producing wells in southeastern New Mexico, most of which are in Lea County. The company currently is drilling three exploratory and six development wells in Lea County. Conoco also operates a refinery at Artesia, division exploration offices in Roswell, division marketing offices in Albuquerque, and both district production and district geological offices in Hobbs.

Waterflood Increases Production in Texas

A waterflood project in Pecos County, Texas, has increased oil production to 300 bbl a day, from 14 bbl a day, on a lease of the Carmack Drilling Company. Ultimate maximum production is expected to be 700 bbl per day.

George Buckles, of Buckles and Hostetler, waterflood consultants, who engineered the project, expects an ultimate recovery of 4000 bbl of oil per acre.

Prior to flooding, the company was producing from 13 wells. Seven of these were converted into injection wells, and 6 continued as oil wells. Three more injection wells and 3 additional oil wells were drilled. All of the increased production is from 2 wells.

The water used is obtained at 325 ft and is pumped to the Carmack wells and 11 injection wells of The Texas Company, on an adjoining lease, by 2 F-60 LCR Triplex pumps, made by The National Supply Company. Injection is at the rate of 3600 bbl a day. Water pressure, originally at 500 psi has been increased to 750 psi, and may be raised to 800 psi.

The Texas Company, which has 10 oil wells, has had no increase so far. Results on waterflood depend on rate of injection, thickness of pay section, and how much liquid has been removed. Approximately 40,000 bbl of water must be injected to realize any increase from the offsetting oil wells.

Starit tank battery

Maracaibo's Bush City, Kansas,

waterflood follows planning

Recovery since development began is approximately 2000 bbl an acre—ultimate recovery expected to reach 4000 bbl an acre

A WATERFLOOD property comprising 80 developed acres known as the Starit Lease is operated by the Maracaibo Oil Exploration Corporation in eastern Kansas. It is within the Bush City Shoestring extending for several miles and consists of more than 1500 oil-productive acres, most of which are now being waterflooded or have been in the past. This shoestring is located southeast of Garnett in Anderson County. Recovery will exceed 2000 bbl per day in first 2 years. Ultimate expected recovery is 4000 bbl per day.

Reservoir Characteristics

At the outset there were several old pumping wells on the property and 3 wells that had been cored for analysis. From this and other sources it was possible to establish some useful data.

The formation is called the Squirrel sand and is at an average depth of approximately 760 ft. It consists of alternate sand and shale layers throughout and resembles in many respects the physical characteristics of the Bradford third sand in the Bradford field of Pennsylvania.

The dry air permeabilities of the pay sand layers are moderately low but show a rather uniform distribution throughout the reservoir on the Starit Lease. The porosity of the pay sand is in a satisfactory range, averaging about

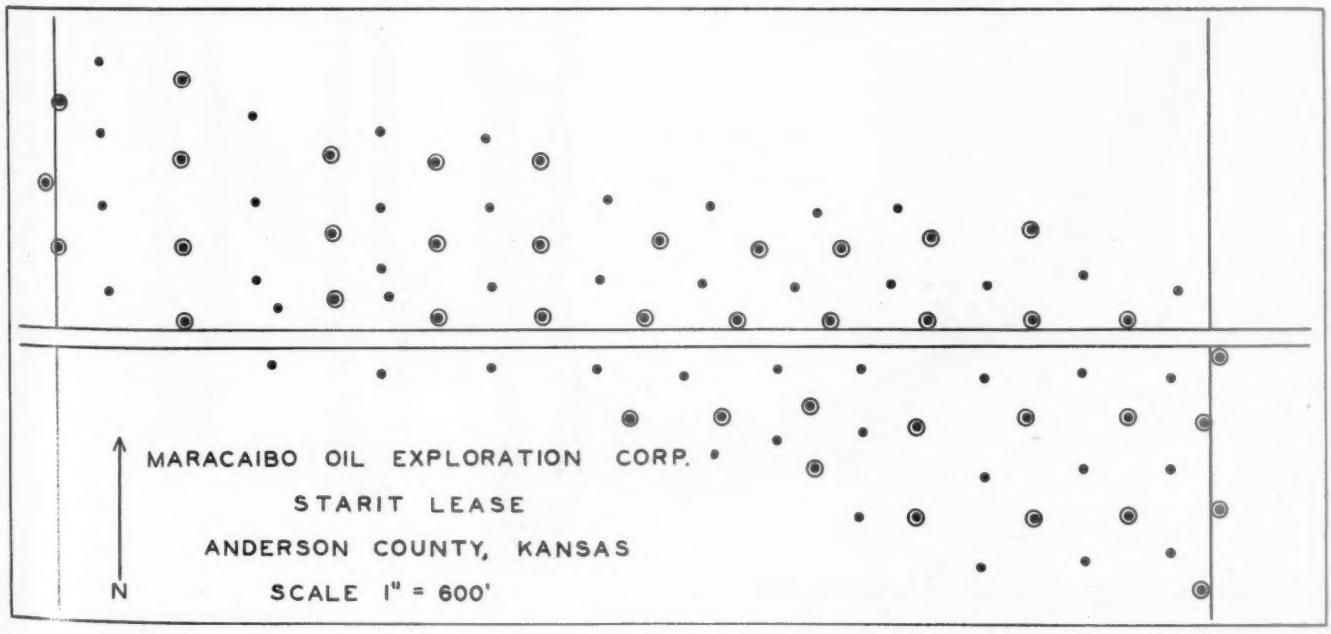

FIG. 1.

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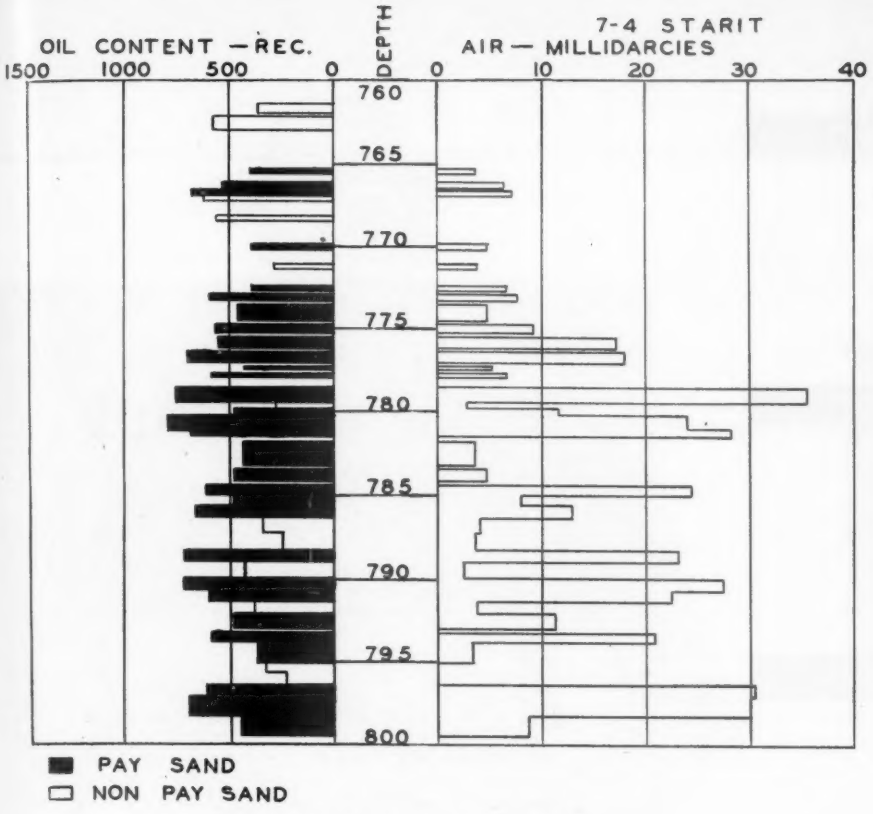


FIG. 2. Sands of Starit lease

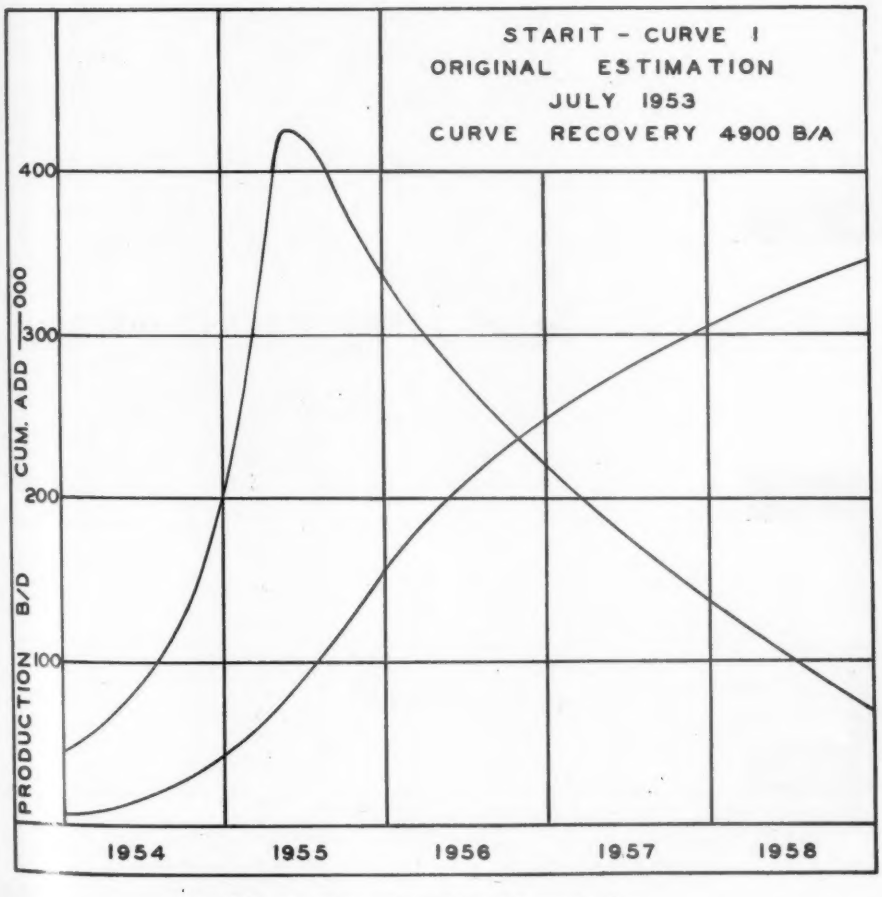


FIG. 3. Curve of anticipated production

18 per cent. The residual oil saturations are of a magnitude to permit waterflooding. The crude oil measures 36.6 deg API at 60 F with a viscosity of 5.7 centipoises at 81 F. All factors being considered , there was every indication that such a property would favorably respond to water flooding efforts, and as a result a decision was made to proceed with further investigation.

Investigation of Reservoir

Additional coring of the structure, the most vital phase of the plans to be later formulated, was taken originally in 5 wells. Chip-coring was mainly used in order to remove the sand from the well bore quickly and without water contamination so that it could be observed in the laboratory under the best possible conditions. A characteristic core profile is illustrated.

Recapitulation of Core Data from Well No. 7-4:

Total sand	23.8 ft
Pay sand	19.2 ft
Reservoir pore space of pay sand	25,800 bbl/acre
Average oil saturation of pay sand	39.6%
Oil content of pay sand	10,200 bbl/acre
Millidarcy feet of pay sand	274
Recovery—as corrected downward	4500 bbl/acre

All cores were examined thoroughly. The structure was found to be better than that illustrated toward the shoestring center and to possess less pay sand on the north and south edges. The top of the sand was found to decline a total of 35 ft from the east line to the west line, whereas bottom of the sand declined 25 ft within those limits. It was thought that the north and south edges were reasonably known so that the probability of drilling dry holes could be considerably reduced.

All known data were then assembled. The information revealed the desired spacings as well as expectations of oil recovery as it related to time. The well spacings established the extent of development costs as well as capital expenditures. The operational costs were estimated from the time factor previously calculated to be under 5 years.

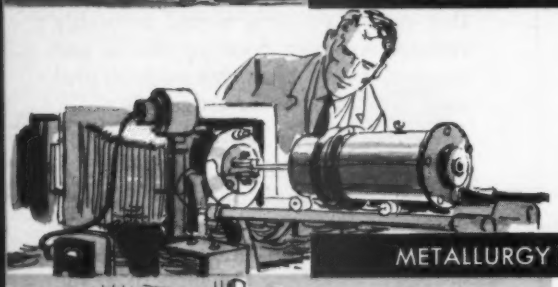
Further reservoir studies revealed the probable rates of injection from which possible oil production could be projected. A curve of anticipated production (Fig. 3) was then prepared, which upon translation into dollars of income supported management's decision to proceed with development.

Planning and Development

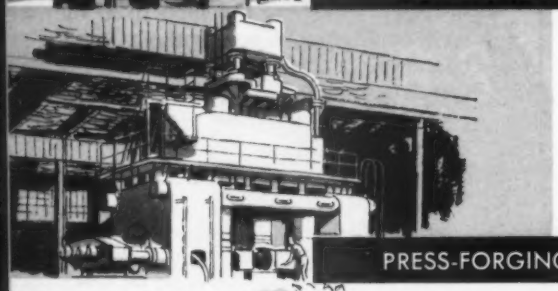
Three separate plans of development were prepared and submitted for management's decision. Each entailed a complete economic study varying in relation to spacings and allied income-expense.

One plan invited favorable consideration. While it represented higher development expense, it also suggested a quicker return of more dollars. That

STEEL MAKING



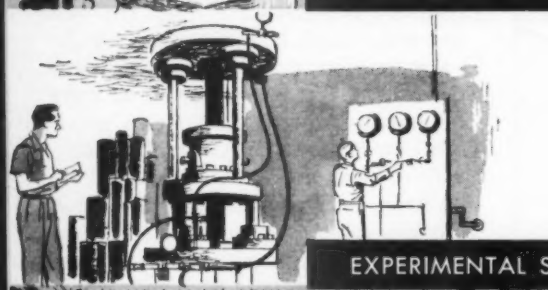
METALLURGY



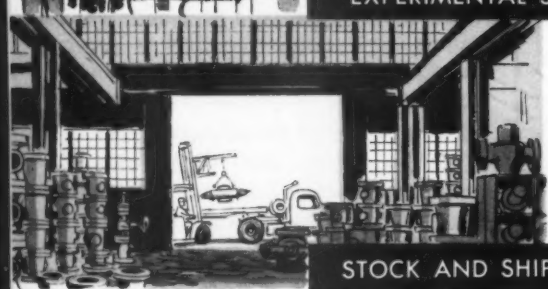
PRESS-FORGING

PRODUCT DESIGN

MANUFACTURING



EXPERIMENTAL SHOP



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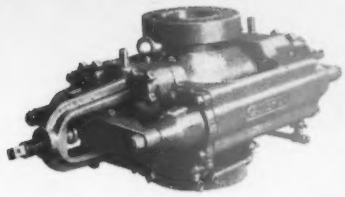
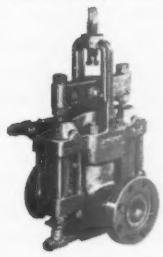


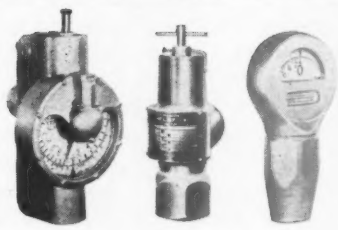
QRC PRESSURE OPERATED
BLOWOUT PREVENTERS

SS PRESSURE OPERATED
BLOWOUT PREVENTERS



HCR PRESSURE OPERATED
FLOWLINE GATE VALVES

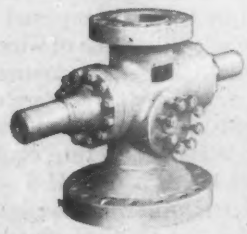
FLEX-SEAL MUD VALVES



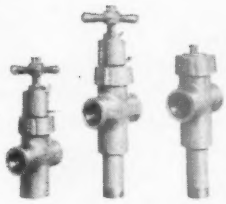
WEIGHT INDICATORS

SHEAR RELIEF VALVES

MUD LINE PRESSURE GAUGES



COMPLETE WELL HEAD
EQUIPMENT AND VALVES



PRODUCTION CHOKES

SAFETY XMAS TREES

plan, which was accepted, involved among other things:

1. All old oil wells would be used, wherever practical, and water wells would be spaced around them.
2. The top 2 ft of the oil pay formation would be forsaken.
3. All oil wells would be pumped —flowing was not considered.
4. Cement-lined pipe would be used throughout where practical.
5. Water of excellent quality was available for purchase from neighbors, thus eliminating the necessity of erecting and operating a plant.
6. Only cable tools would be used in well completion work.
7. All wells would be chipped through the sand.
8. All sand either would be correlated in the Ottawa office or analyzed in a laboratory.
9. All wells would be shot selectively—using as large as 5½-in. shells.
10. A complete and thorough job would be done throughout the development in an attempt to eliminate any later remedial work and the resulting expense.
11. Development would continue to the end without interruption.

As in any other development of this kind, all factors evolved around economics, which still appeared favorable in spite of a high cost of development on an acreage basis.

The development was started in August, 1953, and concluded 14 months later. During this time there was no deviation in the items of planning as above mentioned. During development of the lease, in full accordance with the plans, 36 water wells and 15 oil wells were completed. A total of 31 old oil wells, some of which required reconditioning, were continued in operation. No dry holes were drilled. All oil wells were equipped with electric jacks. Water wells were equipped with cement-lined, 2-in. SMLS and individual meters. All drilled wells were selectively shot and were thoroughly cleaned out after the shot prior to running any pipe. Rag packers were used in all water wells.

All oil well working barrels were set at the top of the sand in a manner so that the oil sand would be covered with oil almost continuously, thereby discouraging any undesirable deposits upon the sand face.

Approximately 2 weeks after intake well completion, injection was started. Within a reasonable amount of time thereafter most wells were opened wide to full line pressure of about 700 psi.

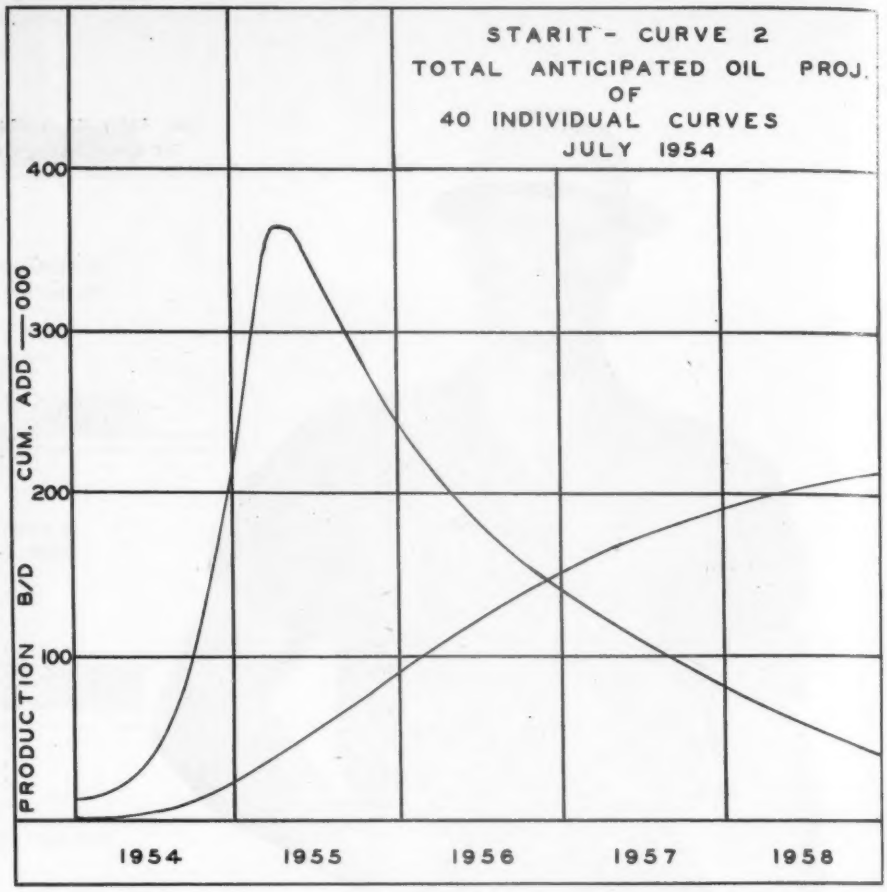


FIG. 4. Anticipated results from waterflooding

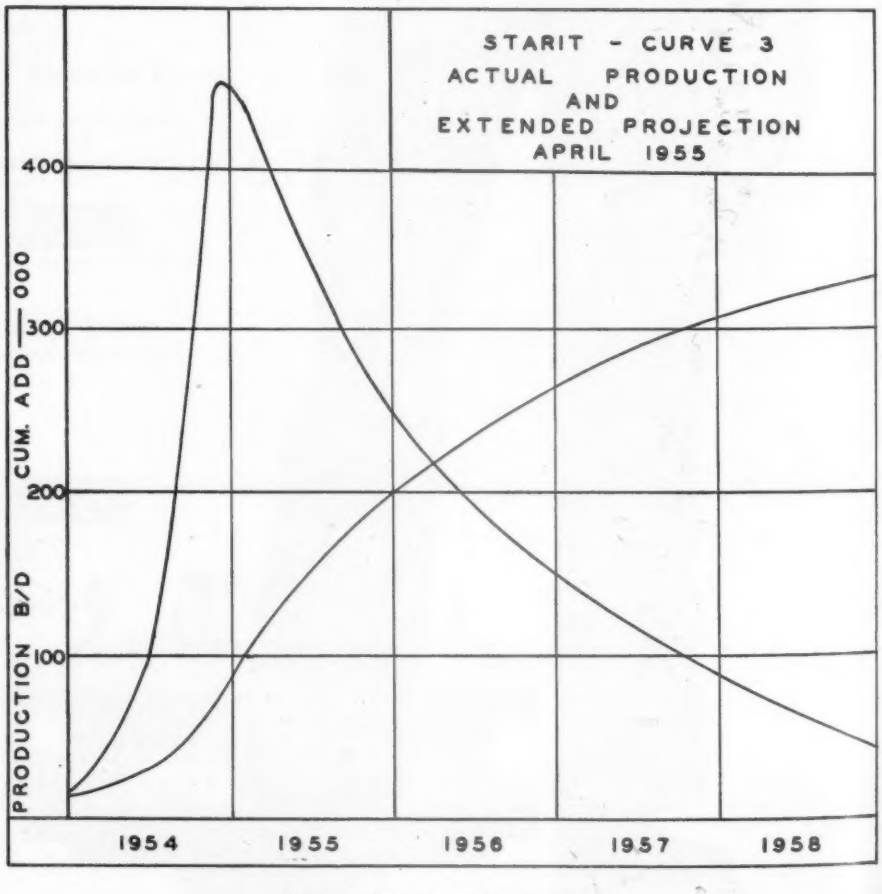


FIG. 5. Actual production results

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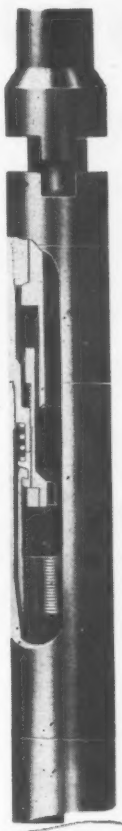

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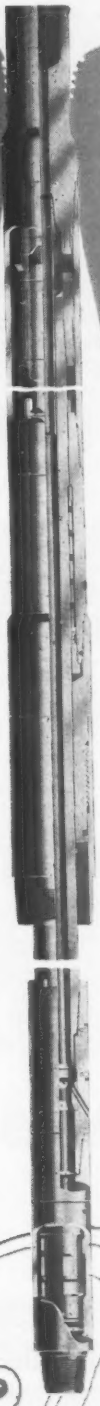

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As injection wells around individual oil wells were subjected to full line pressure it became possible to project in theory the cumulative water traveling toward the individual oil wells. Anticipated curves of individual oil wells were projected as the facts of injection rates came to light. In the final analysis there were 40 curves in all—5 were omitted—each attempting to indicate the productivity of the individual oil well as well as its ultimate recovery.

From the summation of these curves we were provided with another and newer look at the possible expectations, and although it did not correspond with our original projection, it was nevertheless founded on more available facts (See Fig. 4) and thus became more acceptable for future use. Reserves were then revised downward. It was clear that we would not accomplish our original expectations, but as 5 good wells (at that time not drilled) had been omitted, it was probable that we could hope for better results than Fig. 4 indicated. It was concluded that somewhere in between the two curves probably would be the actual end result.

Operation

Good pumping procedure, to which this company adheres, has been practiced throughout the operation. Water injection pressure allowables were reviewed and revised weekly, and most of the wells were found to take water at desired rates.

Originally it had been our plan to spend no more than 3 years on this property after development completion, and up to the date of this writing we have seen no evidence that would justify a change of opinion.

Actual production results are shown in Fig. 5 as projected from March 31, 1955. While by some standards the property may not be considered prolific, it was thought that what heretofore may have been considered a 7 or 10 year operation could be reduced considerably and what we lacked in oil recovery could be compensated for by reduction of time.

Reservoir Performance

The following data summarized the reservoir performance to date:

Area under flood	80 acres
Possibile pay sand average thickness	14 feet
Number of water intake wells per acre	.45
Number of oil wells per acre	.57
Oil production per acre at peak	6.0 barrels per day
Water injection per acre at peak	20.0 barrels per day
Recent produced water/oil ratio	1.5 to 1.0
Total water injected to March 31, 1955	8300 barrels per acre
Oil produced to March 31, 1955	1550 barrels per acre
Water produced to March 31, 1955	1700 barrels per acre

Conclusion

Nothing in the planning, the development, or the future operation had been left to chance. W. T. Umbarger, the superintendent, C. S. Beckwith, the pumper, and all other personnel were made thoroughly cognizant of all the factors involved, including the economics of the situation. It is to them and their organized efforts that any success of the Starit project is attributed.

August 1955 will mark two years since development inception. The results of our planning have materialized favorably in every way and the element of error has been negligible. It is anticipated that by August of this year we will have produced 50 per cent of all the oil that we originally expected, at which time the income that will have been received from oil sales will more than have exceeded expenses for development needs, capital, and operational expenditures. No attempt has been made, however, to show as an element of costs any amount for administrative overhead or corporate taxes.

While we have no assurance that the Starit will fulfill our future anticipation, neither is there any reason to believe otherwise. If it does so respond, it can then be classified as a completely successful project. * * *

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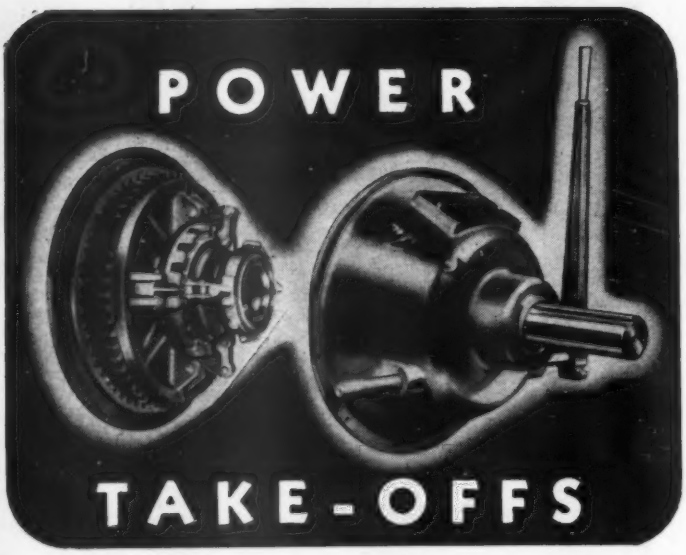

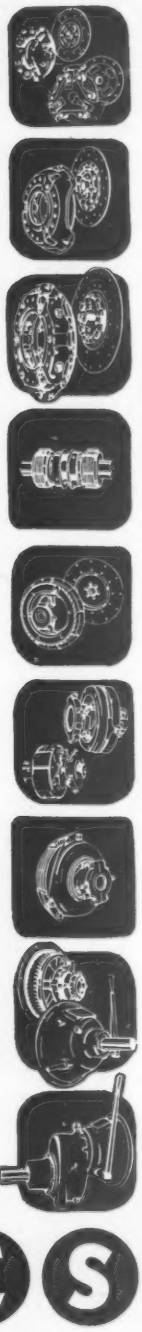

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and R. R. Darner
W. H. Hammon, Wichita Falls, Texas

OF the six units of the KMA reservoir, a Strawn pool of North Texas, three have been subjected to waterflood activity since June, 1950. The units that have been, or are, active projects, have been designated as Units 3, 5, and 6. Unit 3, which was discussed in Part 2, consisted of the W. H. Hammon and Warren Petroleum Corporation Hammon Project, and the Warren Petroleum Corporation Fassett and Tuttle Project. Both these floods are active.

Units 5 and 6, in the southwest part of the KMA field, are produced from two zones. In this area the reservoir rock is composed of sediments that grade from limestone through sandy lime to sandstone with thin streaks of shale. The average porosity is 16.5 per cent for Zone I and 16.1 per cent for Zone II. The estimated connate-water saturation is 17.5 per cent for Zone I and 20.0 per cent for Zone II. The average permeability is 84 md for Zone I and 216 md for Zone II.

Gas injection, still in operation, was begun into the reservoir on a large scale in January 1940. During December, 1953, approximately 12.3 per cent of the gas produced from Unit 5 was returned to the reservoir, equivalent to 297 cu ft per bbl of oil produced from the unit.

Two of the projects in Unit 5, the LeBus Oil Company-Lewis project, and the LeBus-Lewis waterflood projects have been abandoned. The LeBus, Mangold, Blackwell-Oil-and-Gas Company, Hodges, and the Tide Water Associated-Mangold projects are active.

A discussion of individual projects in Unit 5 follows.

EXCLUSIVE

LeBus Oil Company LeBus Project

The LeBus Oil Company began injecting water into its LeBus well No. 2 during July, 1951. This well is completed with open hole penetrating Zone II of the KMA formation and is in the W. H. Spiller survey, abstract 258. The LeBus Oil Company LeBus and Lewis "A" leases are being affected by this injection well.

History Before Waterflooding

Development of the leases in this project was begun in January, 1938, and continued until February, 1939. The LeBus lease contains 100 acres and has seven KMA and two Ellenburger wells. The Lewis "A" lease contains 50 acres and has five KMA and three Ellenburger wells. However, when water injection was started, only two KMA wells (No. 4 and 5) were being produced. A total of 145,421 Mcf of gas was injected into well No. 7 of the LeBus lease from September, 1939, to October, 1944, when the well was converted to a producing well. There was no gas injection on the Lewis "A" lease.

The KMA wells are completed with 7-in. casing, cemented at various depths between the top of the KMA limestone and the top of Zone II. Except for three wells (LeBus wells No. 1 and 2 and Lewis "A" well No. 5), the KMA wells penetrate all of Zone II and 2 to 44 ft of the underlying formation. This open-hole completion procedure exposes 3 to 61 ft of unproductive rock in each well.

Structure maps contoured on top of zones I and II are included as Fig. 12 and 13. The gross thickness of zones I and II is shown in Fig. 14 and 15. The structure maps indicate that both zones dip southward and have a general east-west strike. Zone I is less than 20 ft thick under the LeBus and Lewis "A" leases and shales out entirely immediately south of these leases. Zone I is open to the well bore in some wells, but the amount of oil production from this zone is considered to be negligible. Zone II ranges in thickness from less than 50 to over 70 ft. In some parts of this area, however, Zone II has a dense limestone streak, 10 to 15 ft thick, approximately in the middle.

The leases in the flood-pattern area have a gross productive volume of 8895 acre-ft and an average gross thickness of 59.3 ft in Zone II. Zone I has not been considered because it is believed to have been almost barren of oil.

When waterflooding was begun in July, 1951, 742,769 bbl of oil (4952 bbl per acre) had been produced from the LeBus and Lewis "A" leases. The peak in oil production (11,253 bbl per month) was reached in 1940. The oil production rate has declined continuously since 1946. The month before waterflooding was begun, 733 bbl of oil was produced from both leases.

Development of Waterflood

The flood pattern shown in Fig. 13 contains 24.9 acres. The gross productive reservoir volume of Zone II is 1563 acre-ft, and the average gross thickness 62.8.

The injection of water in the LeBus lease well No. 2 was begun during July, 1951, with a wellhead vacuum on the injection well. Approximately seven barrels of water was injected per day per ft of gross productive thickness during the life of the project.

Source and Treatment of Injection Water

The fresh water used for injection was obtained from a nearby irrigation canal. No produced water was returned to the formation.

A schematic diagram of the water-treating plant is shown in Fig. 16. Injection water for both the LeBus and Lewis projects was obtained from this water-treating plant. The plant was

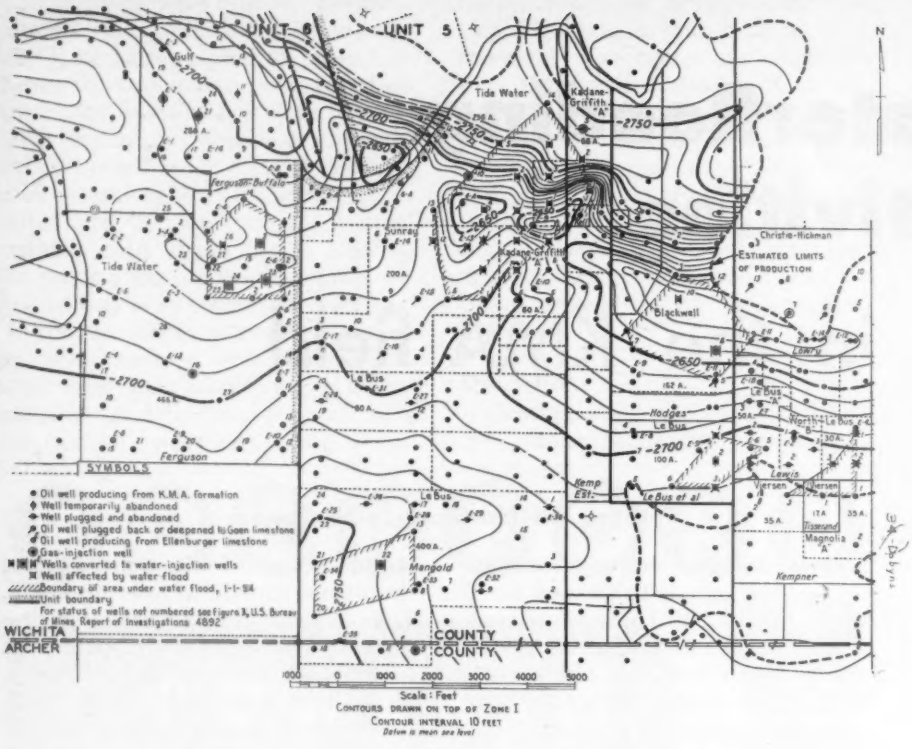

FIG. 12. Structure map of zone I, part of Units 5 and 6

electrically operated and controlled with automatic floats and switches. Water flowed by gravity from the irrigation canal into two earth-storage pits. Two centrifugal pumps moved about 1000 bbl water per day from the storage pits into the treating house, where an electrically driven chemical treater proportioned 50 lb of lime and 5 lb of alum a day into the water.

The water flowed by gravity from the treating house through a concrete ditch to four settling ponds. Two pounds of copper sulfate was added per day at the head of the concrete ditch near an electrically driven, paddle-type agitator that assisted in placing the copper sulfate in solution in the water. The treated water from the settling ponds was forced to the filter by a centrifugal pump. Chlorine was added to the water ahead of the filter by an automatic chlorinator. An open-type filter was used, composed of five grades of gravel and sand. The filter was back-washed once every six months.

The filtered water was pumped by a centrifugal pump into the clear-water tank and flowed by gravity from the clear-water tank to the pumphouse, where a horizontal duplex Gaso injection pump, powered by a 10-hp electric motor, forced the water through 2-in. pipe into the injection well. The volume of water injected daily was measured with a Pittsburgh meter and controlled manually with valves at the injection wellhead.

The wellhead injection pressures during the time the project was active ranged from a vacuum at the start to 650 psi at the end.

No corrosion troubles had been experienced by the operators to the time the project was abandoned. Daily chemical checks were made on the injection water, and the quantity of treating chemicals was changed accordingly. Once each month a complete chemical analysis of the water was made.

Analyses of the chemical constituents of the raw water, clear-tank water, and treated water at the wellhead of Lewis No. 3 are given:

Analysis of raw water

Radical	Ppm
Calcium (as $CaCO_3$)	561
Magnesium (as $MgCO_3$)	19
Silica	6
Manganese	.2
Iron (Fe)	.1
Supersaturation in bicarbonates as calcium carbonate	0
Chloride (as NaCl)	2,223
Sulfate (SO_4)	530
Turbidity	13.0
Carbon dioxide (calculated)	4.8

Indicated pH, 7.5
Speiefic gravity, 1.002 at 60 F.

Analysis of clear tank water

Radical	Ppm
Calcium (as $CaCO_3$)	594
Magnesium (as $MgCO_3$)	106
Silica	5.0
Residual chlorine (Cl_2)	.5
Carbon dioxide (calculated)	0
Total hardness (as $CaCO_3$)	700
Chloride (as NaCl)	2223
Sulfate (SO_4)	475
Iron (Fe)	.1
Turbidity	.6
Supersaturation in bicarbonates as calcium carbonate	.0

Indicated pH, 8.4
Specific gravity, 1.002 at 60 F.

Analysis of treated water at wellhead of Lewis No. 3 (⅓ mile from treating plant)

Radical	Ppm
Calcium (as $CaCO_3$)	583
Magnesium (as $MgCO_3$)	117
Silica	.5
Iron (Fe)	.1
Undersaturation in bicarbonates as calcium carbonate	4
Chloride (as NaCl)	2223
Sulfate (SO_4)	475
Maganese	.2
Turbidity	10
Carbon dioxide (calculated)	2.2
Total hardness (as $CaCO_3$)	700

Indicated pH, 7.3
Specific gravity, 1.002 at 60 F.

Methods of Completing and Operating Wells

As previously stated, the producing wells were completed with the casing set at various depths between the top of the KMA limestone and the top of Zone II. All of the wells were shot with nitroglycerin and completed with open holes. The wells were not recompleted for the waterflooding operation. The producing wells were pumped with individual, electrically powered units and standard subsurface equipment before and during the waterflood.

The water-injection well, LeBus No. 2, was completed with casing set 26 ft above the top of Zone II and with a borehole penetration of 46 ft into Zone II. The well was shot with 140 quarts of nitroglycerin on completion and not recompleted when converted to an injection well; however, during October, 1952, the bottom of the hole was plugged back 15 ft with crushed rock and a cement cap in an attempt to shut off water breaking through to producing wells.

Results of Waterflooding

From the time water injection was begun in July, 1951, to the time of abandonment of the project in January, 1953, 178,481 bbl of water was injected into LeBus well No. 2. During the same period, 11,292 bbl of oil was produced from the LeBus and Lewis "A" leases. The cumulative injected water-produced oil ratio during the life of the project was 15.8. Only a small volume of oil produced during water injection can be attributed to the waterflood. The oil production of the LeBus wells No. 1 and 3 increased; but water broke through, and the increased oil production lasted only a few days. Production statistics are not available to show the amount of this increase in oil production.

Daily well tests during October, 1952, indicated that LeBus well No. 1 produced 1.05 bbl of oil and 35.45 bbl of water and LeBus well No. 3, 3.15 bbl of oil and 5.25 bbl of water. At this time, the injection well was plugged back 15 ft, and daily well tests showed that LeBus well No. 1 produced 1.05 bbl of oil and 15.75 bbl of water and

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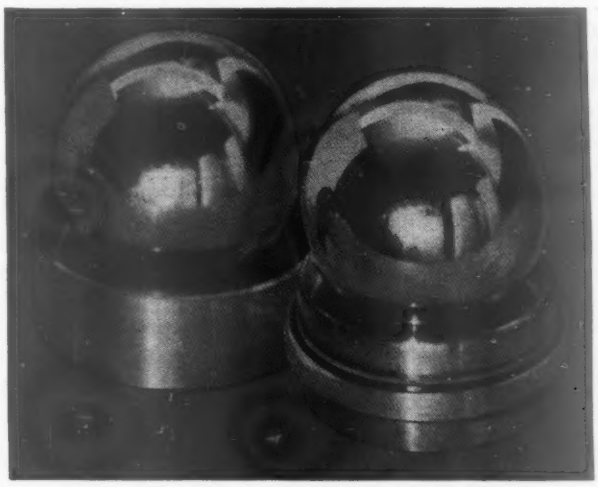

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LeBus well No. 3 produced 2.10 bbl of oil and 2.10 bbl of water.

During November, 1952, however, daily well tests showed that the water was again increasing, with LeBus well No. 1 producing 1.0 bbl of oil and 21 bbl of water and LeBus well No. 3 producing 2.0 bbl of oil and 4.0 bbl of water. The plugback of the injection well reduced water production temporarily but did not result in increased production of oil.

Pertinent data on the project before and during waterflooding are given in Table 1. Water injection was discontinued and the project abandoned on January 28, 1953. The LeBus wells No. 1 and 3, the only wells affected by the waterflood, did not respond favorably.

The three main reasons for failure of this project could be:

(1) Lack of flood pattern. This made it impossible to exercise control over the movement of the reservoir fluids.

(2) Unproductive rock exposed in the well bore. This allows the injected water to move through oil-barren, permeable rock or along sand-shale or limestone-shale contacts.

(3) Unusually high permeability streaks within the oil-productive rock. This allows injected water to channel through the formation without moving a significant volume of oil.

The plugback of LeBus well No. 2 supports item 3, as it reduced temporarily the water production from LeBus wells No. 1 and 3 by about 50 per cent. Core analyses indicate that thin streaks of rock having a permeability as high as 1000 to 1500 md are present in Zone II. Undoubtedly, these thin streaks contributed considerably to channeling of the water, with little increase in oil production. The core analyses from Zone II show that the streaks of rock of high permeability were 1 to 2 ft thick and isolated from beds of moderate permeability (5-200 md) by dense beds with a permeability of less than 0.1 md.

Application of remedial measures to minimize channeling of water would be difficult, because all wells on the LeBus and Lewis leases were shot with nitroglycerin. Three caliper logs from wells completed in Zone II in another area of the field show that the original hole size (5¾ in.) was increased, on an average, to 10 in. in diameter; shale beds showed a hole size over 30 in. in diameter. A 5-in. liner, cemented in the shot hole and selectively jet-perforated, may be a means of excluding the zones of high permeability from the well bore. A moderate squeeze pressure while the liner was being cemented would be desirable, so that cement would be forced into the cavities and high-permeability beds.

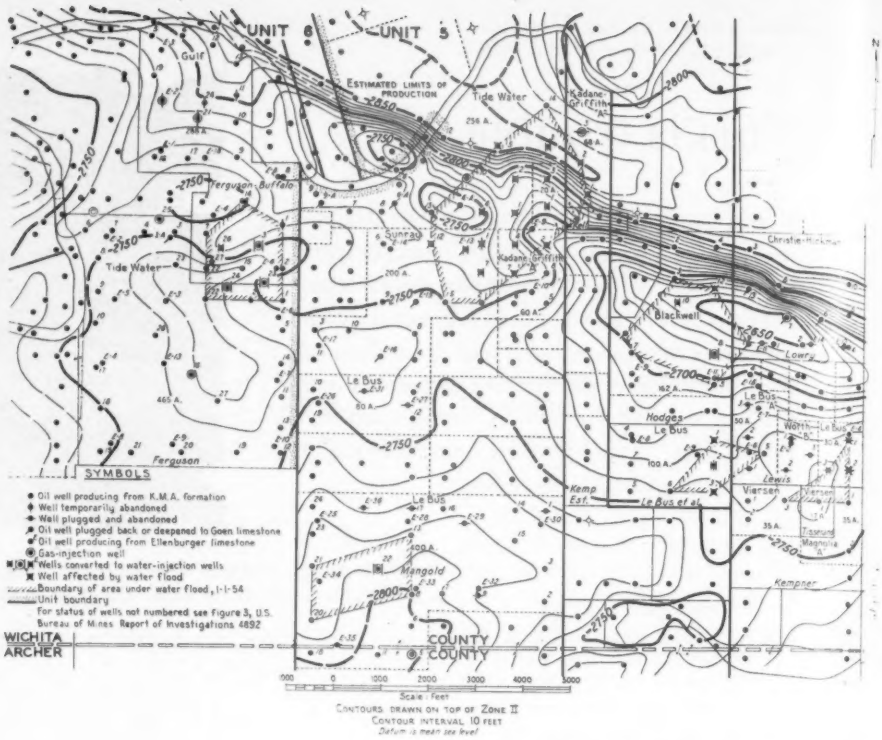


FIG. 13. Structure map of zone II, part of units 5 and 6

No flow-rate surveys were attempted on the LeBus wells to locate the points of exit of injected water from the injection well or points of entry into the producing wells because the boreholes had been shot. Undoubtedly, the injected water was channeling through a thin bed, as the volume of injected water produced from wells No. 1 and 3 was small. The principal reason for abandoning the flood project was failure to increase the production of oil. Little increase in oil production could be expected from one irregular, inverted five-spot pattern, with no possible means of controlling the movement of the injected water.

This injection pattern cannot be expected to produce very favorable results in waterflooding. It has been observed[2] that a one-way push of injected water toward an oil well from one input well increased the oil production approximately one-tenth as much as a four-way push in a five-spot pattern, where the producing well is enclosed by four input wells. When one input well is used, the flood front could move in a preferential direction and form an oil bank in a linear manner. This linear flood front could miss the well bores of offset producing wells, so that oil production would not increase.

LeBus Oil Company Lewis Project

The LeBus Oil Company Lewis project is approximately one-half mile east of its LeBus project and is in the Robert McKim survey, abstract 182, sec. 19 and 20. The project was begun with the injection of water into Zone II through the LeBus Oil Company Lewis well No. 3 in September, 1951.

History Before Waterflooding

The leases considered to be in the flood-pattern area are the LeBus Oil Company Lewis; the S. K. Vierson Kempner and Tisserand; and the Magnolia Petroleum Company Kempner "A". The productive area of the leases in this project is 147.5 acres; the gross productive reservoir volume is 8482 acre-ft, and the average gross thickness is 57.5 ft. Fig. 12 and 13 are maps showing the structural configuration of Zone I and Zone II in the area of the project, and Fig. 14 and 15 are isopachous maps showing the gross thickness of Zone I and Zone II.

Drilling of the wells on the leases was begun in February, 1938, and completed in September, 1939. The monthly oil production reached a peak of 8754 bbl during March, 1940. Oil production for August, 1951, the month before water injection was begun, was 599 bbl.

Gas has not been injected in any wells in this project, and the immediate surrounding area has had only three gas-injection wells; therefore it is considered that the gas-injection program had a negligible effect on oil recovery from the leases in this project. When waterflooding was begun, the total oil

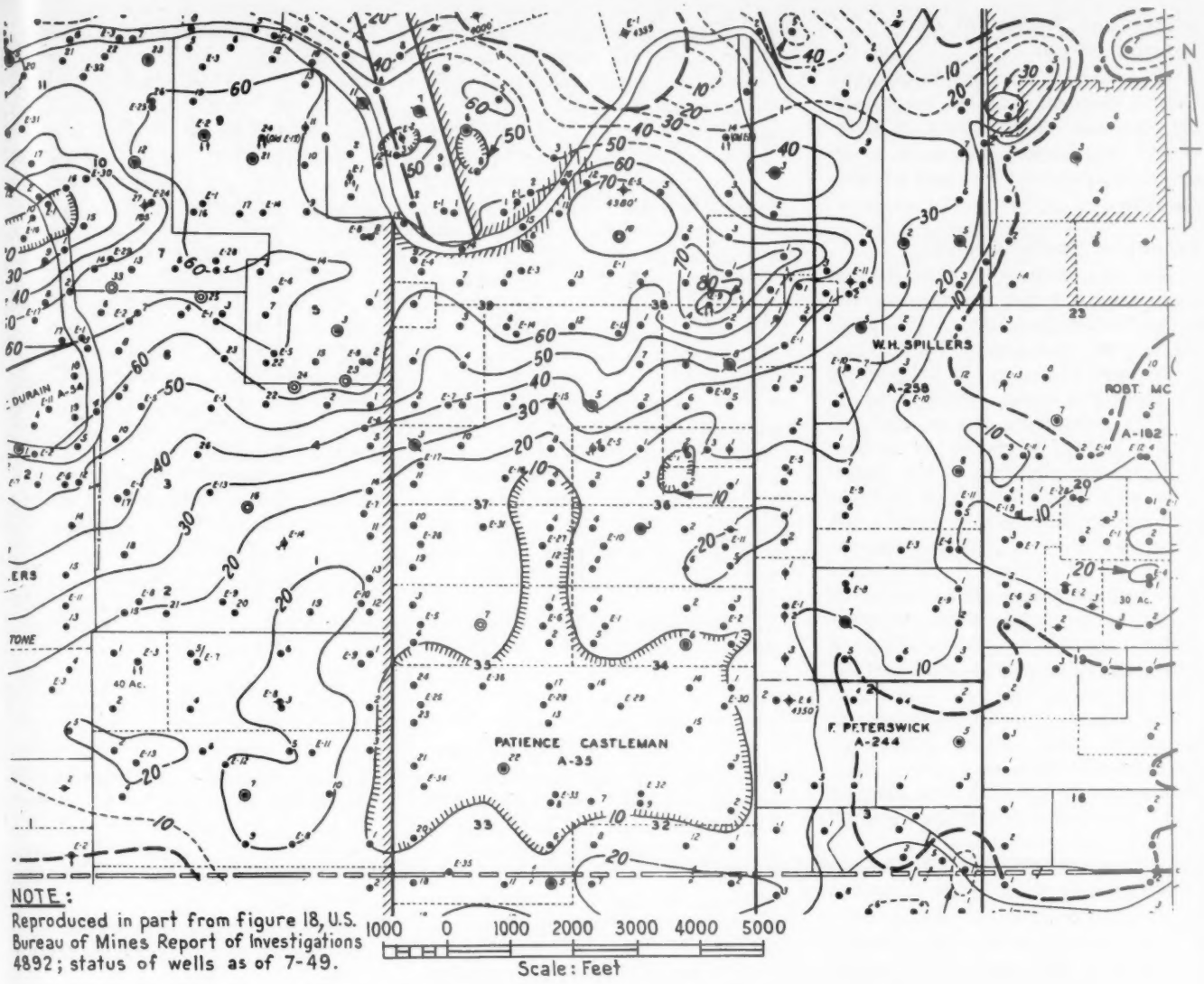


FIG. 14. Isopachous map showing gross thickness of Zone I, part of units 5 and 6 KMA field, Wichita and Archer Counties, Texas

production from the leases was 521,326 bbl, or 3534 bbl per acre.

All wells are completed with the casing set and cemented between the top of the KMA limestone and the top of Zone II. The setting points ranged from 1 to 92 ft above the top of Zone II. All or part of Zone I is open to the well bore in Lewis wells No. 1, 2, and 3. Zone I in these wells probably is barren of oil, but the rock may have enough permeability to transmit water under pressure.

Wells No. 1 and 3 on the Lewis lease have 1 to 2 ft of shale below Zone II open to the well bore. Wells on the Magnolia Kempner "A" and Vierson Tisserand and Kempner leases have 1 to 8 ft of oil-barren rock above Zone II and 3 to 13 ft of shale below Zone II open to the well bore.

All wells in the project were shot with nitroglycerin before water injection was begun.

Development of Waterflood

This project was begun in September, 1951, when fresh water was injected into Lewis well No. 3. Fig. 13 shows the wells considered to be in the flood-pattern area. The productive area of the flood pattern is 18.7 acres and overlays 1126 gross acre-ft of Zone II, which has an average gross thickness of 60.2 ft.

Approximately four months after injection was begun, Lewis well No. 2 began to produce water. In an endeavor to alleviate the water breakthrough, Lewis well No. 3 was plugged back 24 ft. This measure, however, was unsuccessful, as Lewis well No. 2 continued to produce with a high water-oil ratio. Lewis well No. 3 was plugged in September, 1952, after 75,211 bbl of water had been injected, and water injection was begun in Lewis well No. 2 during October, 1952. Subsequently, the water production increased in Lewis well No. 1 (without an increase in oil production) to such an extent that it was uneconomical to produce the well. The flood was abandoned in January, 1952, after 103,724 bbl of water had been injected.

At the start of waterflooding, the water was injected under a vacuum at the wellhead. During the fourth month of operation, a wellhead pressure of 220 to 500 psi was required to inject the desired volume of water. During the 17-month life of the project, the average daily water-injection rate was 200 bbl, equal to 4.7 bbl per day per ft of producing formation for Lewis well No. 3 and 6.8 bbl for Lewis well No. 2.

Method of Completing and Operating Wells

None of the producing or injection wells was recompleted when waterflooding was begun; therefore, 1 to 92 ft of oil-barren rock above Zone II was open to the well bores. LeBus Oil Company Lewis wells No. 1, 2, and 3 had 92, 25, and 42 ft, respectively, of open hole above Zone II.

Electricity was used as the power for the standard pumping equipment installed on the wells.

Source and Treatment of Injection Water

The water for injection on this project was obtained from the water-treating plant used on the LeBus Oil Company LeBus project. The same water-pumping equipment was used for both projects.

Results of Waterflooding

The only increase in oil production attributable to water injection was observed during December, 1951, when the oil production from Lewis well No. 2 increased from 5 to 16 bbl per day for about two weeks. During January, 1952, a production test of the well showed 5 bbl of oil and 80 bbl of water a day. Lewis well No. 3, the water-input well, was plugged back 24 ft the same month, and the water production in Lewis well No. 2 decreased temporarily. As the increase in oil production was small and lasted only two weeks, the injected water evidently was channeling to Lewis well No. 2 through a thin, highly permeable section of the producing formation.

No remedial measures were attempted on Lewis well No. 2, although 25 ft of oil-barren rock above Zone II was open to the well bore, through which water could bypass to Lewis well No. 1.

Reasons for the failure of this project to respond successfully to waterflooding can be summarized as follows:

(1) No injection-well pattern, consequently no control of the movement of reservoir fluids could be maintained.

(2) Failure to confine injected water solely to the oil productive part of the formation under flood. This may have allowed water to bypass through oil-barren rock to the producing wells.

(3) Insufficient remedial work to correct water breakthrough or to locate the part of the formation taking water.

Pertinent data on the project before and during waterflooding are given in Table 1.

LeBus Oil Company Mangold Project

This waterflooding project is in the P. Castleman survey, abstract 35 (see Fig. 13). Although the project could be considered a waterflood, basically it is a salt water disposal operation.

Water injection was begun in April, 1951, into the LeBus Mangold well No. 22 after it was converted from a gas-input well. The four producing wells considered to be in the flood-pattern area are shown in Fig. 13. The Mangold lease is divided into two parts, one the 400 acres that form the main part

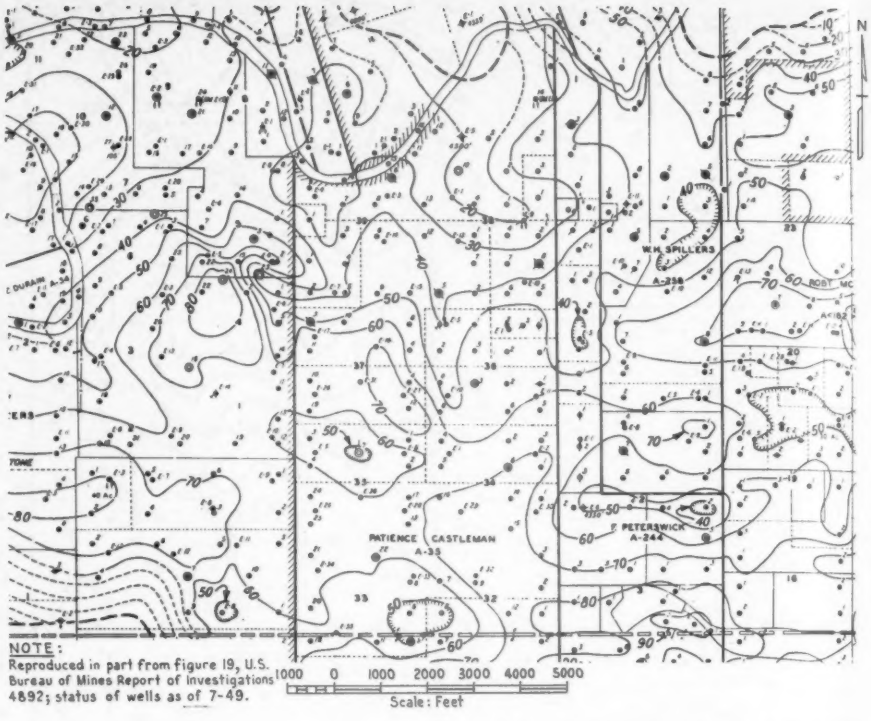


FIG. 15. Isopachus map showing gross thickness of Zone II, part of units 5 and 6

of the lease and the other the 80 acres on which are KMA wells No. 4, 10, 12, and 19. Zone II of the KMA reservoir under the Mangold lease contains 31,318 acre-ft and averages 65 ft in gross thickness. At the time waterflooding was begun, 3621 bbl of oil per acre had been recovered from the reservoir.

The productive area of the flood pattern encloses 56.4 surface acres and covers 3445 acre-ft of Zone II, which averages 61 ft in gross thickness.

The water used for injection is brine produced from Ellenburger oil wells on the lease. The untreated water flows by gravity from the gunbarrel to a 500-bbl storage tank, where an oil seal is maintained on top of the water to exclude air. The water flows by gravity from the storage tank to the well and into the producing formation.

The injection water is not metered. The operator estimated, however, that the water-injection rate during December, 1953, was 75 bbl per day and that the cumulative volume of water injected to January 1, 1954, was 297,000 bbl. On the basis of this estimate, an average of 9.2 bbl per day per ft of producing formation was injected into the input well to January 1, 1954.

Results of Waterflooding

No increase in oil production had been observed in the offset producing wells as a result of water injection to January 1, 1954.

Movement of the injected water could not be predicted because the injected water could not be controlled with one input well. An additional difficulty was presented by 52 ft of oil-barren rock open to the well bore above Zone II. A considerable volume of injected water could have entered this section.

Pertinent data on the project before and during waterflooding are given in Table 1.

Blackwell Oil & Gas Company Hodges Project

This project, which is in the W. H. Spillers survey, abstract 258, is approximately 2000 ft north of the LeBus Oil Company Lebus project. Although one well on the Lowry lease is in the flood-pattern area, most of the area under flood is on the Hodges lease.

History Before Waterflooding

Structure maps of the subsurface configuration of Zone I and II are shown as Fig. 12 and 13, respectively; in addition, the outline of the flood-pattern area appears on both illustrations. The average gross thickness of Zones I and II is pictured by the isopachous maps in Fig. 14 and 15, respectively.

Although Zone I is shown to be 10 to 20 ft thick on the Hodges lease, oil recovery from it probably was small. Zone II, the main source of oil on the 162-acre Hodges lease, has 8944 gross acre-ft of reservoir volume and averages 55.2 ft in gross thickness.

Development of the Hodges lease was begun in January, 1938, and completed in October, 1938, except for well

No. 12, which was completed in August, 1947. All producing wells except No. 12 were completed with 7-in. casing, set and cemented 4 to 87 ft above Zone II. The casing in well No. 12 was set 16 ft into the top section of Zone II. The wells were drilled as much as 110 ft below Zone II.

At the time of completion or later, wells No. 2, 6, and 7 were shot with nitroglycerin, wells No. 1 and 12 were acidized, and wells No. 3, 4, and 5 were both shot and acidized. Wells No. 2 and 4 did not penetrate Zone II completely, and well No. 6 was plugged back 38 ft after the well was drilled 5 ft into the shale below Zone II. Wells No. 1, 3, 5, and 12 are completed, with both the KMA formation and the Goen limestone open to the well bore.

The Goen limestone is oil productive and approximately 50 ft below the base of Zone II. Wells No. 7 and 8 have 4 and 2 ft, respectively, of shale open to the well bore below Zone II. Water-injection well No. 10, which was recompleted from an Ellenburger producer, originally had 10 ft of shale open to the well bore below Zone II, but this well was plugged back and reperforated with jets in the upper section of Zone II.

None of the KMA oil wells on the Hodges lease produced water at the time of completion, but individual well tests conducted during June, 1943, showed that wells No. 3 and 5 were producing approximately 50 per cent water. This water probably came from the Goen limestone, as water has been produced from this formation in other areas of the field.

Approximately 75 Mcf of gas a day was being injected into the producing formation at a pressure of 235 psi through Hodges well No. 8 before April, 1951, when the well was converted for water injection. Gas injection into this well was begun in May, 1940, at a pressure of 1784 psi and at a rate of approximately 60 Mcf per day. About 300,000 Mcf of gas had been injected by the time waterflooding was begun.

The cumulative oil production from the Hodges lease to May, 1951, (at which time waterflooding was begun) was 789,087 bbl or 4871 bbl per acre.

Development of Waterflood

Water was first injected into Hodges well No. 8 April 25, 1951. Approximately 125 bbl water per day was injected, with a vacuum at the wellhead.

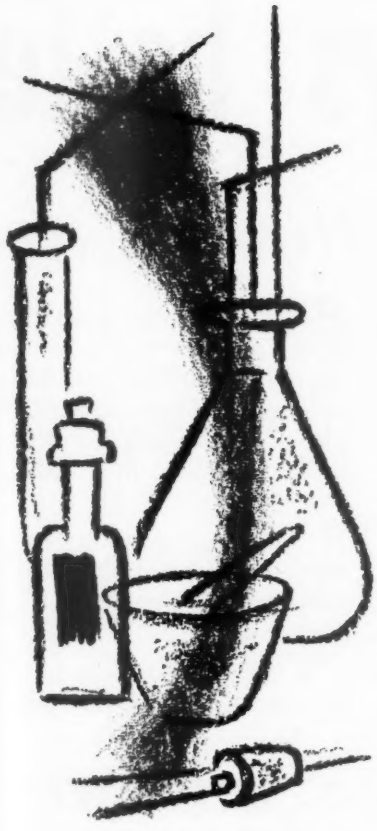
During August, 1952, well No. 10 was recompleted, and water injection was begun at a wellhead pressure of 400 to 500 psi. Since then, water has been injected intermittently into either or both wells, depending on the supply of water available. Records are not available on the volume of water injected into each of these wells or the times at which they were used for injection purposes. After the injected water channeled to well No. 12 from well No. 10, most of the water has been injected into well No. 8. Well No. 10 has been used only when the supply of water available for injection has exceeded the capacity of well No. 8 to take water without wellhead pressure. When this condition occurs, the water is pumped into both wells. On January 1, 1954, the injection rate was approximately 100 bbl per day.

The surface area enclosed by the flood-pattern is 80.7 acres. The gross volume of Zone II in the flood-pattern area is 4976 acre-ft, and the average gross thickness is 61.7 ft.

Method of Completing and Operating Wells

Well No. 8 on the Hodges lease was converted from a gas-input to a water-input well, and the injection of water was begun in April, 1951.

During August, 1952, Hodges well No. 10 was plugged back from the Ellenburger formation, and the casing was jet-perforated with 45 holes oppo-



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Analyses of customers' field brines, cores, and cuttings are made by expert chemists, petroleum engineers, and geologists at our Breckenridge lab. All our stations have modern portable equipment for on-location checking of brine and spent acid. Our Guymon and Odessa labs are equipped to make complete analyses of brines and formation cuttings.

Also important to our customers is the research that our lab does on new materials and new processes for well servicing, the continuous review of our quality control, the re-evaluation and improvement of materials and processes used by our service units in the field, and the constant study of other products and methods as they are introduced to the industry.

So our lab is a significant part of the service work our customers receive. It's one of the reasons our crews do such a good job. Nowhere in the oil patch will you find a better outfit . . . with better men, better equipment, or better facilities. The Chemical Process Company • Breckenridge, Texas • Service Stations Throughout the Mid-Continent Area.

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THE CHEMICAL PROCESS CO.

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site 22 ft of the lower section and 24 holes opposite 6 ft of the upper section of Zone II. The 22 ft in the lower section of Zone II was then hydraulically fractured at a maximum pressure of 1850 psi and a minimum pressure of 1000 psi. A total of 2500 lb of sand was used.

Water was then injected into this well after the fracture treatment. As the injected water channeled to well No. 12, the lower section of Zone II was plugged off in December, 1953, and 10 more ft of casing opposite the upper section was jet-perforated.

None of the KMA wells on the lease was recompleted to seal off unproductive rock open to the well bore. Water-injection well No. 8 has 16 ft of unproductive rock open to the well bore above Zone II and from 0 to 110 ft below Zone II.

The producing wells are pumped by standard surface and subsurface equipment.

Source and Treatment of Injection Water

Water produced with the oil from the 1700-ft Gunsite sandstone, from the KMA reservoir, and from the Ellenburger reservoir is used for injection. The water is stored in a 500-bbl tank and is either pumped or flows by gravity into the injection wells directly from the tank. The water is not treated, and air is not excluded from the system.

Results of Waterflooding

No increase in oil production has been observed as a result of waterflooding to January 1, 1954. However, the volume of water injected has been small when compared with the oil production during waterflooding. The lack of a flood pattern and the amount of unproductive rock open to the well bore probably are important factors contributing to the lack of response to the injected water. This project may never respond favorably to waterflooding unless some type of development pattern is used and the unproductive rock and the Goen limestone are sealed off from the well bore.

An average of only 1.4 bbl water per day ft of gross productive formation had been injected to January 1, 1954. This small rate of injection cannot be expected to fill the voids in the reservoir in a reasonable time; normally a large portion of the void space in the reservoir must be filled before oil production increases.

The injected water from input well No. 10 may have channeled to producing well No. 12 on the Hodges lease through fractures established when the input well was hydraulically fractured; therefore, the bypassing condition cannot be considered indicative of the susceptibility of the formation to flooding.

Pertinent data on the project before and during waterflooding are given in Table 1.

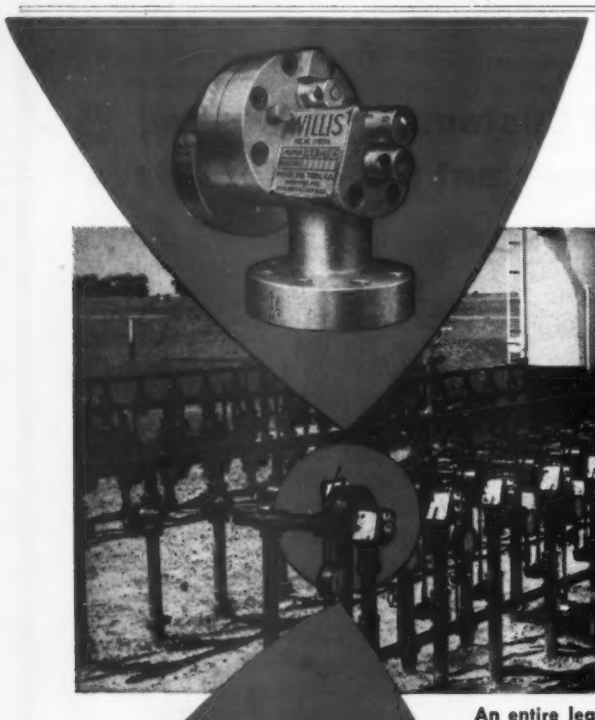
Flying Frac Unit

A "flying pump" will be used by Imperial Oil Limited for acid frac work in northern Alberta and British Columbia, Canada.

The pump, an F-60 Triplex, made by The National Supply Company, will be flown to locations that are virtually inaccessible by other means of transportation. There are no service companies in the area, similar to those that operate in other parts of the oil country.

A 14-28 per cent solution of inhibited HCL is used in the frac work. The pump is equipped with 1⅛-in. plungers and operates at 400 rpm. Intermittent pressures may be as high as 6,000 psi.

Power already in place on the rigs will be used to drive the pump, to eliminate the necessity of transporting additional power equipment.



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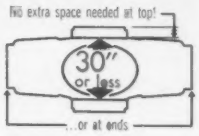
When you buy cellar control gates, compare the important *extra* values you get in Shaffer equipment — space-saving compactness, time-saving convenience, maintenance-saving simplicity and ruggedness — and you'll see why so many operators agree that Shaffer is far and away the industry's top value in blowout protection.

Extra Value #1



SPACE-SAVING COMPACTNESS!

Equipment that is bulky and cumbersome exacts a high toll in greater rig costs, deeper cellar requirements, clumsy hook-ups. Shaffer Hydraulic Gates require a minimum of space — in height, width and length . . . as little as 18½" total height for the 13⅜" (12" Series 900) Single Gates, only 30" for the same size in Double Gates (with two compartments unitized into one body).

And no extra space is needed at the top or ends to allow space for changing rams!

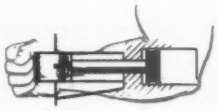
Extra Value #2

EASY RAM CHANGES

As wells are drilled rams must be changed frequently to meet requirements of varying pipe sizes. In Shaffer Hydraulic Gates you simply open two doors in the side of the body, slide out the ram assembly, change rams, replace the assembly and bolt the doors shut. Closing the doors automatically aligns the rams within the body. And complete ram changes can be made with equal ease whether the pipe is in or out of the hole!

What's more, there's no need to dismantle the upper compartment to change rams in the lower one — or vice versa. Rams in either compartment are changed with equal ease!

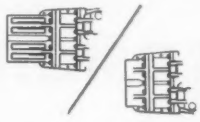
Extra Value #3



POSITIVE DIRECT DRIVE

In Shaffer Hydraulic Gates there are no yokes or complicated secondary hook-ups between rams and operating cylinders. For positive action, fewest parts, simplest maintenance, the hydraulic cylinders are directly behind the rams — on the same shaft. And note how all operating parts are completely enclosed within the gate body, protected from corrosion or damage.

Extra Value #4



RISING or NON-RISING SHAFTS

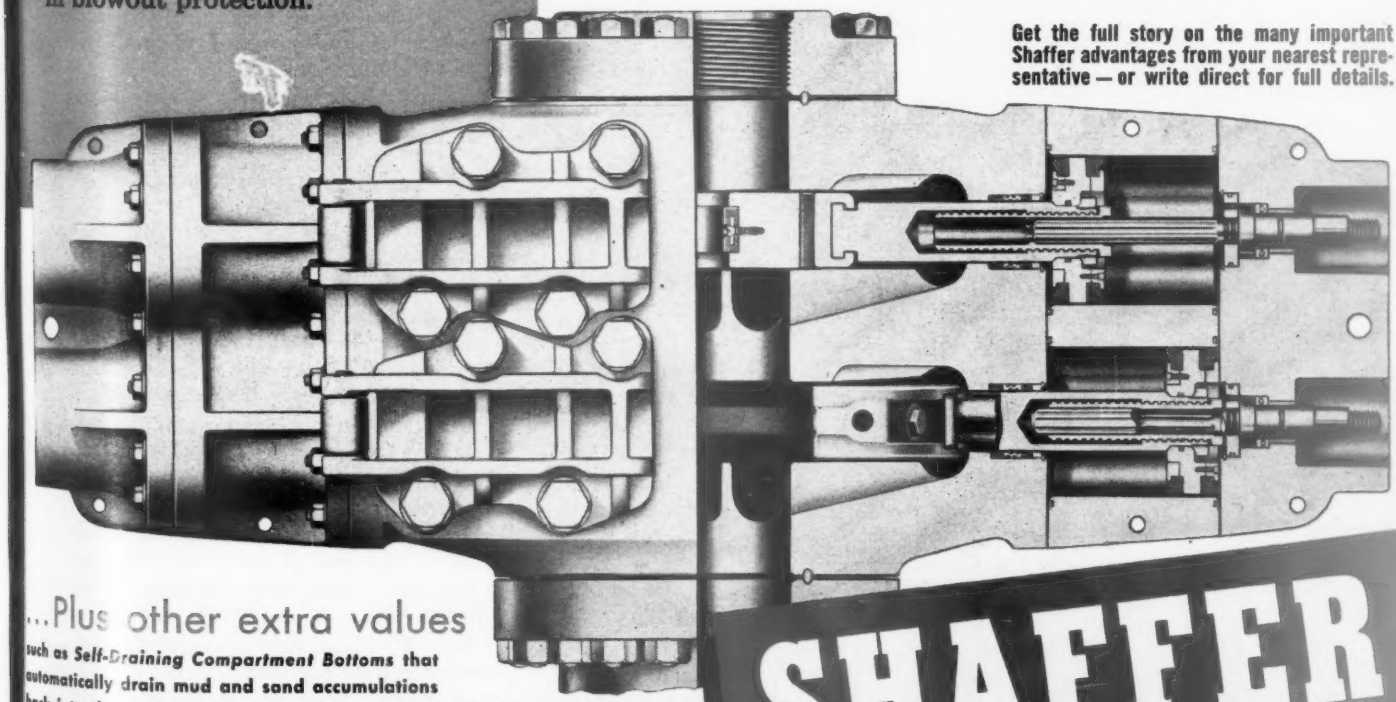
Some operators prefer a non-rising locking shaft for the greater compactness it makes possible. Others prefer a rising shaft for its quick indication of ram position. Take your choice — Shaffer, and only Shaffer — provides whichever design you prefer. And whether the shaft is rising or non-rising, built-in body extensions protect the shafts against damage in all positions!

Extra Value #5

MAXIMUM VERSATILITY

Shaffer provides a choice of either Double or Single Hydraulic Gates, whichever best meets your requirements. Rams and most other parts are interchangeable, size for size, between Single and Double Gates, assuring maximum adaptability to your particular needs — at minimum inventory and maintenance costs.

Get the full story on the many important Shaffer advantages from your nearest representative — or write direct for full details.



...Plus other extra values

such as *Self-Draining Compartment Bottoms* that automatically drain mud and sand accumulations back into the well . . . *Completely Enclosed Design,* with no moving parts exposed where they can become wedged or damaged by timbers falling into the cellar — or corroded by salt muds or chemicals . . . and *Field-Proven Dependability* backed by over three decades of pressure control leadership and advancement.

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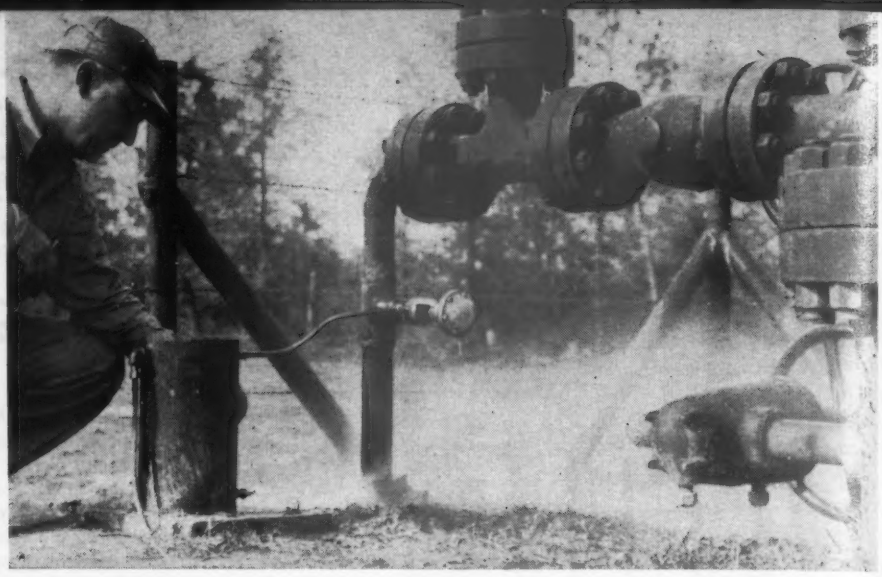
▲ Plastic bottles are used to take liquid samples from drips. The samples are tested for iron content to determine the extent of corrosion



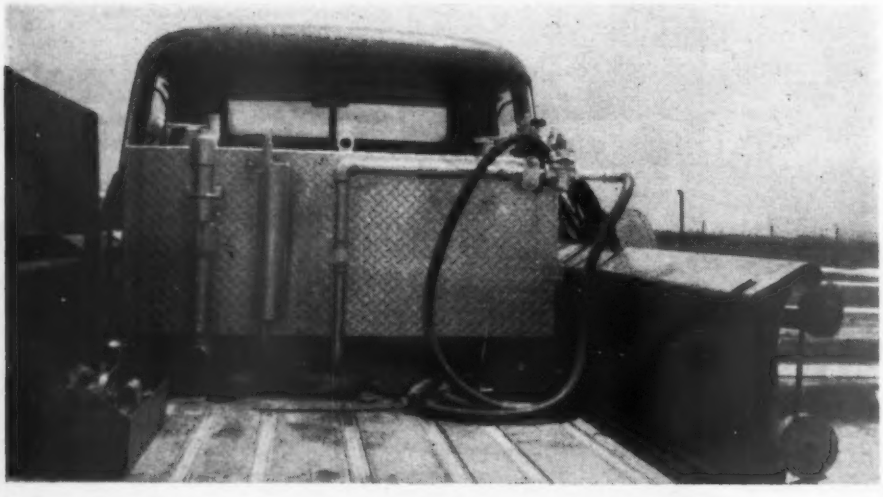
▲ Drips should be blown daily to prevent the accumulation of water in gas supply lines to high pressure inhibitor injection pumps

Jack L. Wiggins
Consulting Engineer

P 432.611

Corrosion Control in Texas Gas Fields

▼ An ammonia tank is shown here installed in the bed of a pick-up truck. It is used to transport ammonia from the warehouse to the well. Brass fittings are avoided and the gage glass on the tank is protected by a swinging cover. The tank is equipped with regulators and safety pressure valves

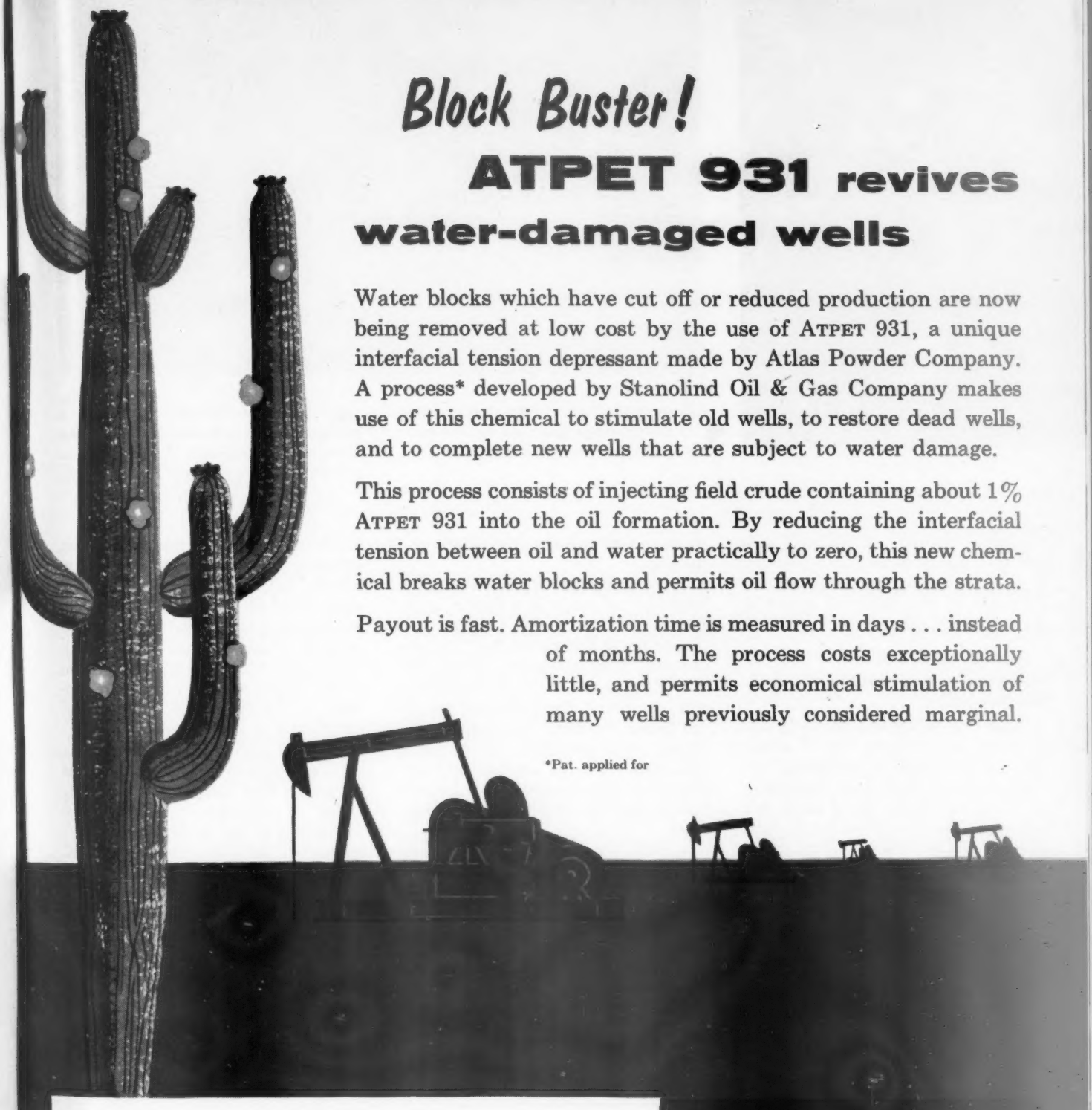


CORROSION of oil and gas equipment offers a challenge to many who are engaged in countering its costly effects. Not only does corrosion result in the loss of material and equipment, it also appears as a continual threat in gas areas where line blowouts and other failures disrupt service, close down production, and halt delivery during critical winter months. This threat exists in both field gathering lines and production equipment, and many companies are steadily engaged in the detection and prevention of the damaging effects of corrosion and corrosive moistures that collect in lines and installations, and destroy thousands of dollars worth of equipment every month.

In the Carthage field in East Texas, an entire gathering system is being gradually converted from a micarta sleeve and washer protected line to an anodic protected line. Each connection that previously had been fittted with micarta insulating material, is now being uncovered and equipped with metal jumpers that allow electric current to flow over the insulating material.

While these preventive measures are being perfected, a constant search is underway in this same gathering system to locate highly corroded sections of gas lines which, in some instances, are carrying pressures of 2500 psi. Therefore, it becomes necessary to uncover sections of field lines that engineers' contour maps show to be low in elevation. Water often collects in these low areas, and it is axiomatic that where water is present corrosion is accelerated. The pieces of line that have been cut out with acetylene torches are

EXCLUSIVE



Block Buster!

ATPET 931 revives water-damaged wells

Water blocks which have cut off or reduced production are now being removed at low cost by the use of ATPET 931, a unique interfacial tension depressant made by Atlas Powder Company. A process* developed by Stanolind Oil & Gas Company makes use of this chemical to stimulate old wells, to restore dead wells, and to complete new wells that are subject to water damage.

This process consists of injecting field crude containing about 1% ATPET 931 into the oil formation. By reducing the interfacial tension between oil and water practically to zero, this new chemical breaks water blocks and permits oil flow through the strata.

Payout is fast. Amortization time is measured in days . . . instead of months. The process costs exceptionally little, and permits economical stimulation of many wells previously considered marginal.

*Pat. applied for

ATPET 931 is non-ionic; gives excellent performance in the presence of oil field waters and brines, and has little tendency to plate out on solid surfaces. Write your nearest Atlas office for samples and further information.

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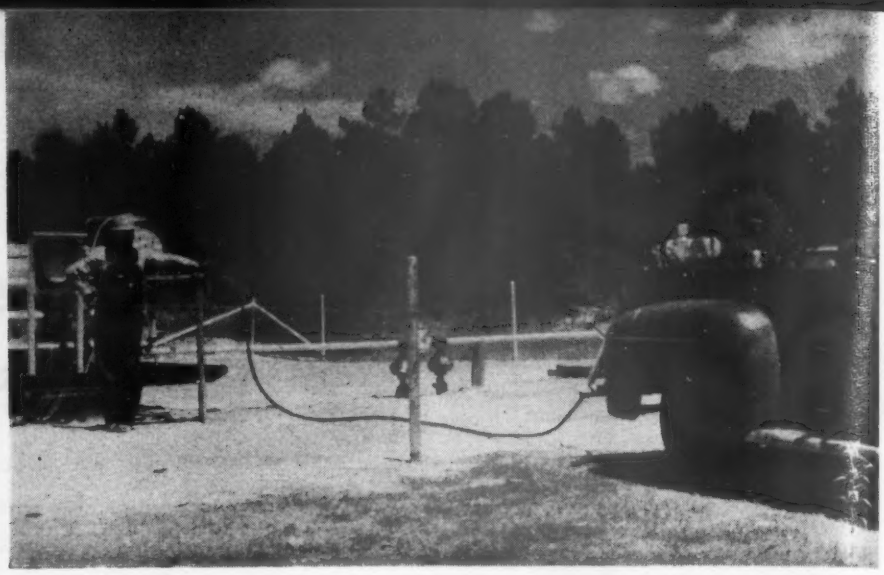
Vertical lubricators of this type are used in the Carthage gas field for the injection of liquid corrosion inhibitors



Corrosion inhibitor equipment is portable on this operation, and one pump serves several leases

removed, repaired, or replaced with new line, and re-welded into position. In other instances gamma-ray pictures are taken to determine the extent of corrosion inside the line.

Measurement of Inhibitor Effectiveness

Since it is nearly imperative in safe operation to know the rate of corrosion, many methods of measuring corrosive activity have been developed. Tests are continually being made, not only to measure corrosion but to measure the effectiveness of corrosion inhibitors that are being applied to the system susceptible to damage. Obviously, this measurement would be necessary to determine which type of inhibitor is most effective in each situation.

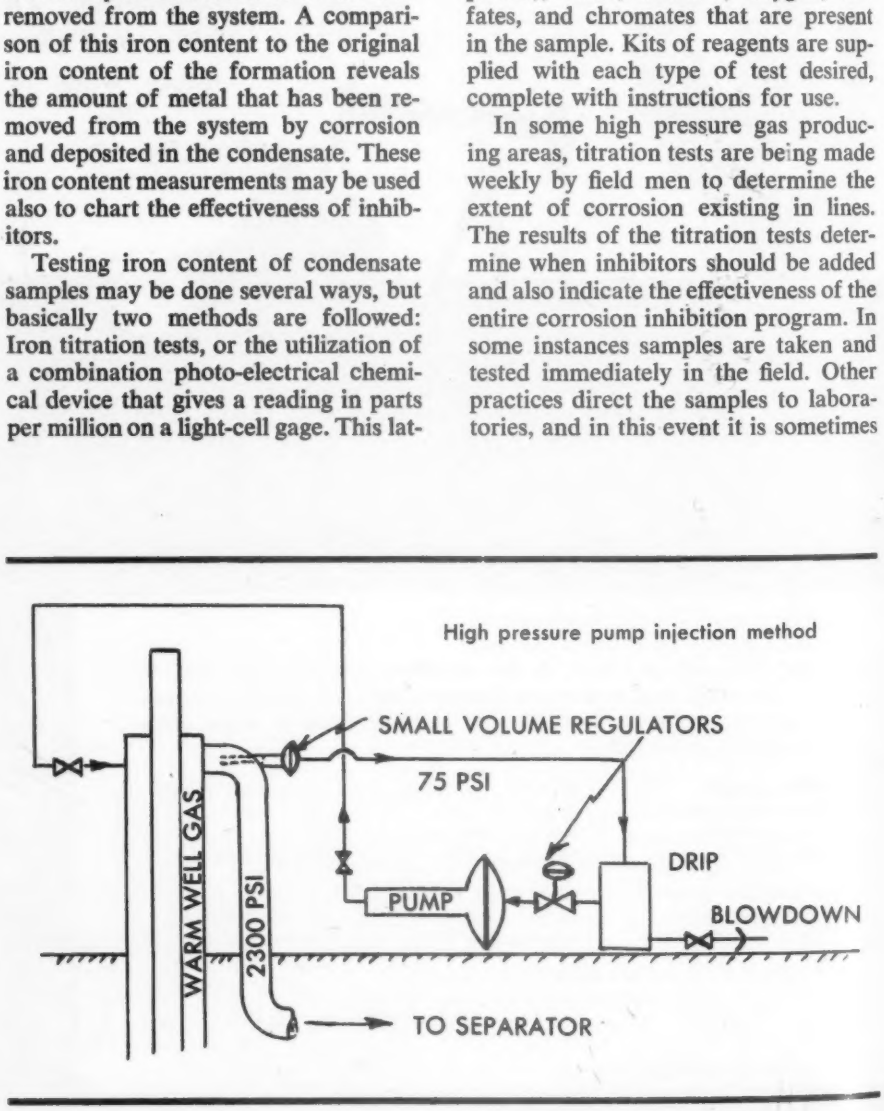
The use of metal tabs or coupons is generally employed to arrive at the rate of corrosion in gas lines at any given point. These metal coupons are placed in the gas stream at designated locations, having previously been carefully weighed. They are allowed to remain in the corrosive stream for a definite length of time; then they are removed and weighed again. The loss of metal from the coupon is an indication of the degree of corrosion taking place in the metal of the gas line at that point. Or, if an inhibitor is being added to the corrosive stream, then the loss of weight in the coupons will furnish some data on which to estimate the effectiveness of the inhibitor.

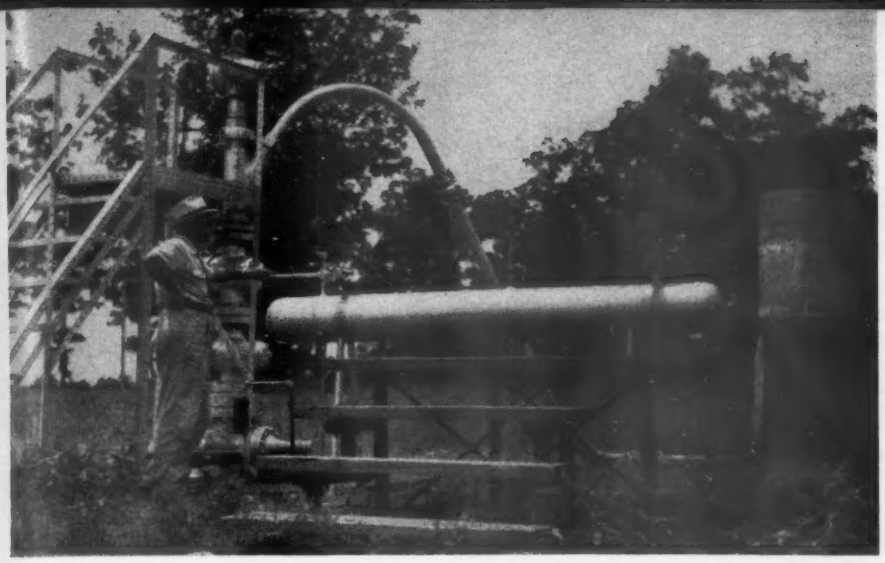
Metal tabs or coupons may be installed by a patented device that permits the inserting and removal of coupons in a line while it is under pressure, or they may be installed in shop-made holders, which are attached to bull-plugs that screw on nipples welded into the line.

Another method of determining the extent of corrosion in a system is the measurement of the iron or metal content of liquid condensate that has been removed from the system. A comparison of this iron content to the original iron content of the formation reveals the amount of metal that has been removed from the system by corrosion and deposited in the condensate. These iron content measurements may be used also to chart the effectiveness of inhibitors.

Testing iron content of condensate samples may be done several ways, but basically two methods are followed: Iron titration tests, or the utilization of a combination photo-electrical chemical device that gives a reading in parts per million on a light-cell gage. This latter device eliminates human error in evaluating the solution color, which, in essence, determines iron content. One such device will determine the amount of iron, phosphates (total and polyphosphates), silica, alumina, oxygen, sulfates, and chromates that are present in the sample. Kits of reagents are supplied with each type of test desired, complete with instructions for use.

In some high pressure gas producing areas, titration tests are being made weekly by field men to determine the extent of corrosion existing in lines. The results of the titration tests determine when inhibitors should be added and also indicate the effectiveness of the entire corrosion inhibition program. In some instances samples are taken and tested immediately in the field. Other practices direct the samples to laboratories, and in this event it is sometimes





▲ Sodium bicarbonate mixed in the concrete tank in the background is placed into this horizontal lubricator for corrosion mitigation in East Texas. Steps and a platform facilitate filling the lubricator

Stick inhibitor material is used in many Texas gas fields to prevent corrosion ▶

convenient and more practical to collect the samples in plastic bottles.

Injection of Liquid Corrosion Inhibitors

Corrosion inhibitors in liquid form are being injected into gas wells in the Woodlawn area, north of Marshall, Texas, by use of a diaphragm pump capable of opposing high pressures. The pump will place the inhibitor in the gas stream against full well pressure of 2300 lb, thereby eliminating the use of lubricators or solid stick injection.

This method of corrosion inhibition requires a constant supply of gas pressure, as does any diaphragm pump. Supply gas will form hydrates and freeze when reduced from certain high pressures to 30 psi required for operation of the diaphragm pump. Preventive measures may be taken to retard this freezing and insure a constant gas supply.

One widely used method of preventing supply gas failure because of freezing is the application of gas well heat at the point of initial pressure reduction. This application of heat is made through the use of a small high-pressure regulator that utilizes the heat of the gas stream. The regulator is equipped with a long nozzle that extends into the center of the warm gas stream. Expansion from high to low pressure is accomplished by an orifice in the tip of the nozzle where heat to prevent freezing is available from the stream of gas itself. Additional regulators attached to the diaphragm pump further reduce supply pressure until operating pressure is reached.

This method of inhibitor injection lends itself to controlled amounts, however small, and a very slow rate of injection is possible. In the Woodlawn area, liquid inhibitors are being added by a pump that operates at one stroke per minute.

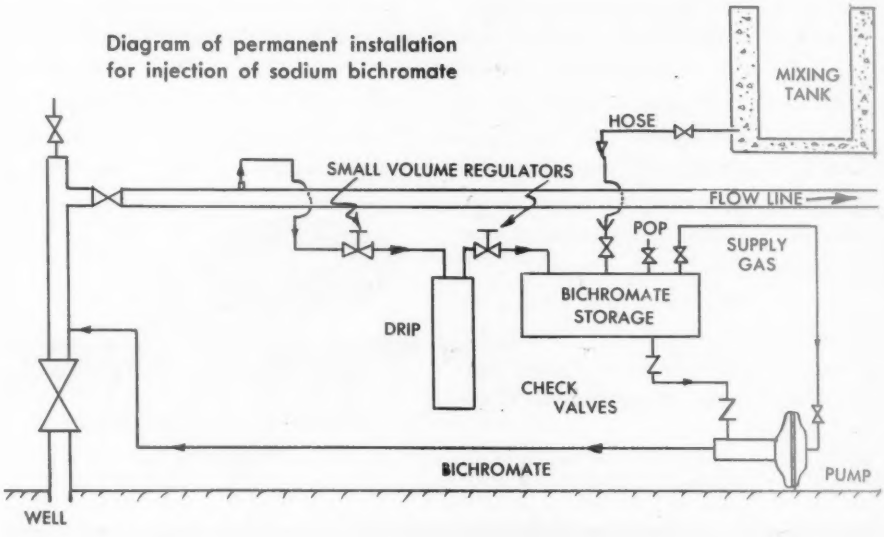
Another method of preventing the freezing of supply gas is the elimination of moisture from the gas by installation of a shop-made drip. Water in gas supply lines tends to cause hydrate formation and causes pump failures with attendant interruption of corrosion treatment. The drip should be blown down daily to dispose of accumulated moisture.

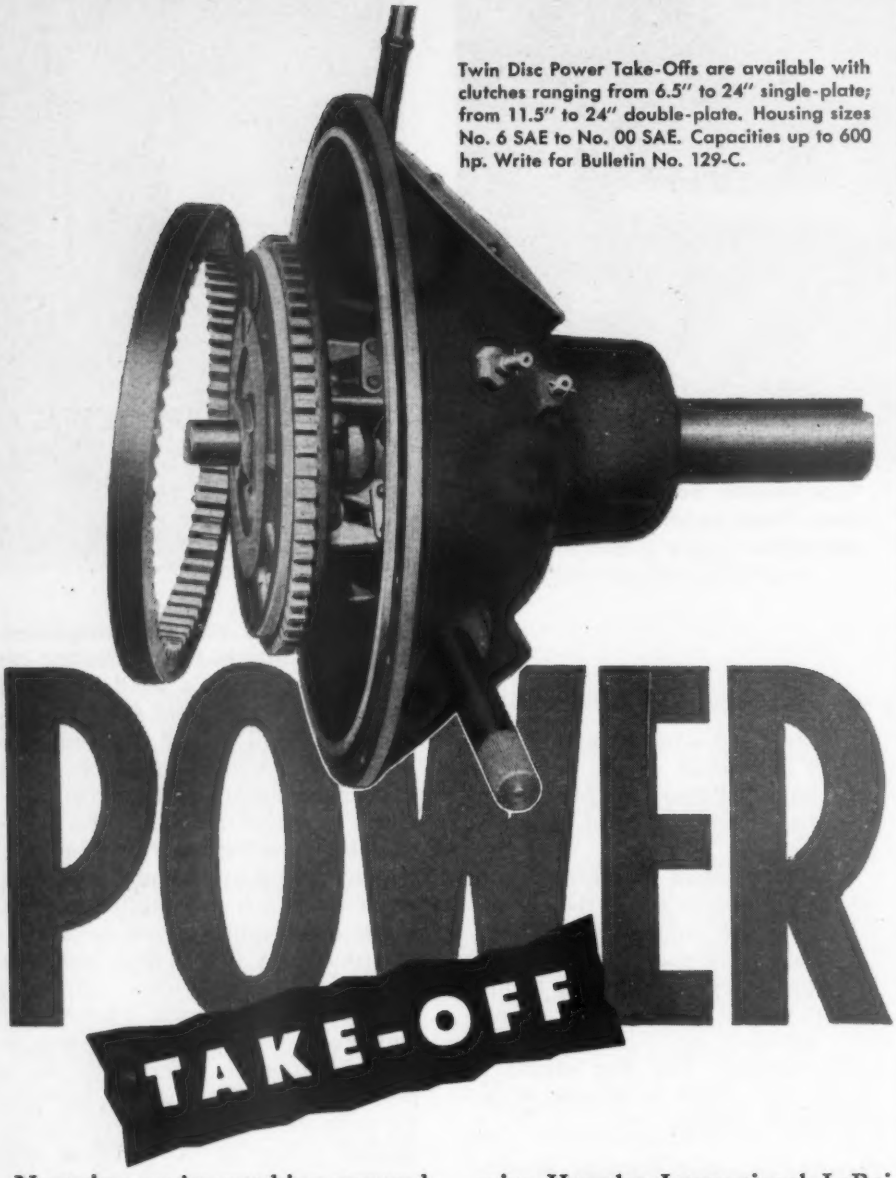
Portable Injection Equipment

Off-shore wells on the Gulf Coast are also served with a corrosion inhibitor by a unique method. A diaphragm pump with attached high pressure gas hoses is installed in a small craft, and pumpers pilot the boat from well to well, anchoring it and attaching the hoses to the wellhead for supply gas to operate the diaphragm pump and to inject a corrosion inhibitor. This practice eliminates the necessity of installing high-priced equipment on off-shore leases where it is continually subjected to the deterioration of salt water.

Around Bay City, Texas, wells are treated with anhydrous ammonia through an arrangement whereby the ammonia is transferred to the well in a tank mounted permanently in a pick-up truck. The ammonia is transferred to the lease supply tank by attaching a hose to the wellhead and using a regulated pressure to force the ammonia into the lease tank from the truck tank.

Diagram of permanent installation for injection of sodium bichromate





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Since ammonia reacts with brass, all fittings must be steel or iron. Also, ammonia may become a safety hazard when handled. Its fumes are pungent and dangerous. A completely safe method has been devised whereby the liquid ammonia is unloaded from dock to truck. This unloading is accomplished by fitting the dock drum with a long spigot that has been screwed into the head opening, then placing a slight, regulated pressure in the drum, forcing the ammonia out through the spigot into truck tank.

The truck tank is equipped with a sight glass and a calibration scale which reveals the amount of ammonia in the tank. The sight glass is protected by a swinging guard which is kept closed except when filling the tank. Only enough ammonia is placed in the tank to meet the requirements of the leases, so that no appreciable amounts of ammonia remain in the truck container.

Operators handling ammonia inhibitors should be instructed in their use in order to insure safe operations.

In other gas areas, high pressure diaphragm pumps are loaded periodically into truck beds and hauled to leases which require the injection of corrosion inhibitors. With the use of long, high-pressure hoses the gas for operating the pumps is brought from the wellhead and reduced with several regulators. A predetermined amount of inhibitor liquid is then forced into the well. The hoses and fittings are removed, taken to another lease requiring injection of inhibitors, and so on, until all of the wells requiring service have been visited. This arrangement eliminates the duplication of equipment at each lease, making it possible for one diaphragm pump to serve several wells.

Permanent Injection Equipment

In some areas it has been found that constant injection is necessary to prevent corrosion, and on these locations there have been installed permanent installations for the injection of either solid or liquid corrosion inhibitors. One such installation in East Texas was built for the injection of sodium bichromate as an inhibitor. Sodium bichromate is also an inhibitor that must be handled with care. It attacks the skin and membranes of the body and should not be breathed. It is a powder and must be poured into vats and mixed with water. Operators using sodium bichromate should be instructed in safe procedure.

After the solution is mixed and prepared it is moved to a pressure tank by gravity flow, since the mixing vat is built higher than the pressure tank. This pressure tank contains not only the liquid, but also serves as a volume

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tank for diaphragm pump supply gas that has been taken from the gas line and reduced with small-volume regulators. Ball and seat check valves on the discharge line of the diaphragm pump are protected from the corrosive effects of the sodium bichromate by a water-resistant grease which is applied through a grease fitting.

Bichromate is also injected by use of a horizontal lubricator. The mixed inhibitor is run to a lubricator after it has been mixed in a concrete vat. Wooden steps and a platform faciliate the addition of the inhibitor.

A vertical lubricator is used for corrosion inhibitor injection in the Carthage field. Liquid is added to the lubricator after the gas pressure has been released.

Solid Inhibitor Injection Equipment

Gas wells in the Bay City area are sometimes treated with solid sticks of corrosion inhibitor. The sticks are dropped through a special head into the tubing and will dissolve as they fall by gravity. With this type of treatment the wellhead must be equipped with an installation that acts as a liquid lubricator. Stick inhibitors are added daily in varying number depending on the requirements of treatment for the particular installation involved. It was found that evenly spaced injection of solid sticks was more effective in this area than periodic injection. In other words, better protection resulted from one stick every day than five sticks every five days.

Inhibitors

A survey of the inhibitor market shows that a dozen different manufacturers are furnishing corrosion inhibitors to the industry under many different trade names. In many areas formaldehyde, potassium dichromate or sodium bichromate are used as corrosion inhibitors, while in other areas trade-name inhibitors are used almost exclusively. Many oil company engineers are making a systematic survey of inhibitors to determine which will be most effective in particular areas.

Corrosion inhibition apparently is coming to be an accepted part of gas production in many areas, and the operation of testing equipment, injection equipment, and the handling of inhibitors has come to be a part of the present day duties of field operators and pumpers.

It is also evident that corrosion inhibition is a vital problem in gas areas of Texas, although methods of treatment and injection may differ widely. *

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Special barges used for many tasks: Removing paraffin from tubing and flow lines, cleaning and painting Christmas trees, wire line work

WORKHORSE of the marshes

MOST interesting of workhorses in the bayou and marshland located oil fields of South Louisiana are the paraffin barges of Gulf Refining Company. These self-propelled units, 60-ft long, 20-ft wide, and 5-ft deep, are operated by two or three man crews who perform such jobs as scraping paraffin from well tubing, steaming paraffin from flow lines, cleaning and painting Christmas trees, running bottom hole pressure instruments and safety valves, and other wire line work.

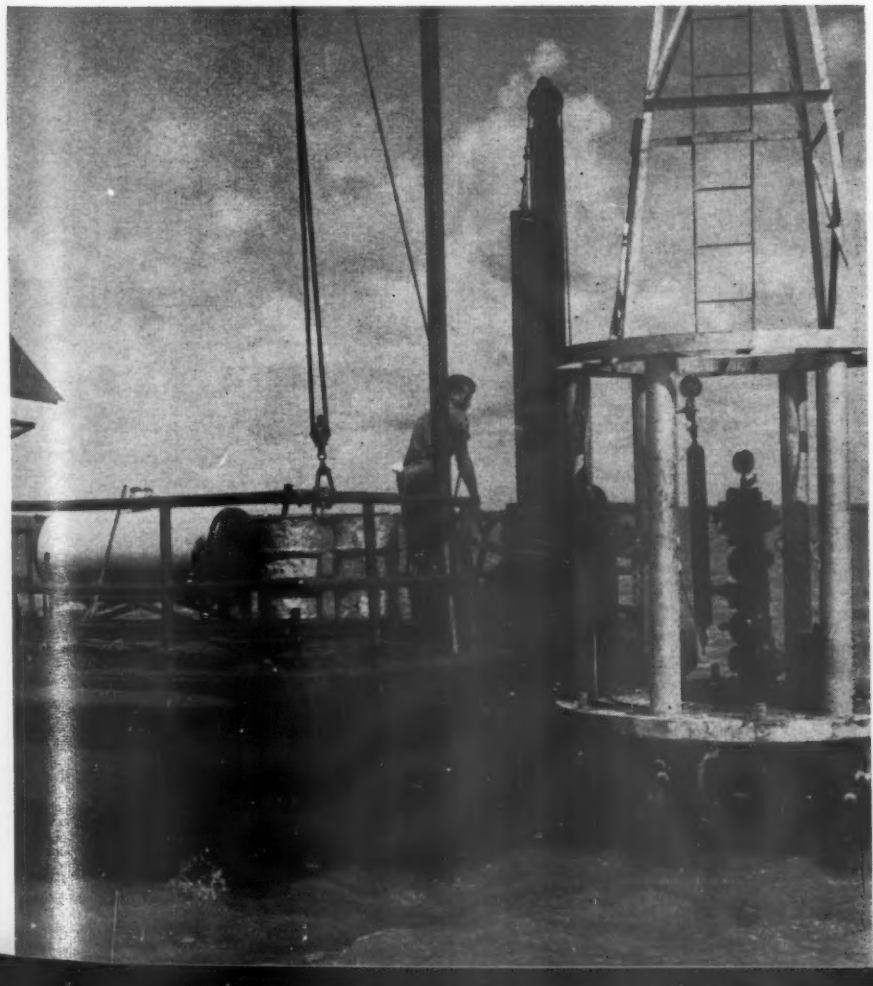
Typical of these operations is that of Barge No. 3724 in Gulf's Timbalier Bay field, approximately 90 miles south and west of New Orleans in LaFourche Parish. This field is supplied from a dock at Leesville, Louisiana, from which the paraffin barge crews travel by taxi boat to the field each morning and return each evening along with other field operating personnel.

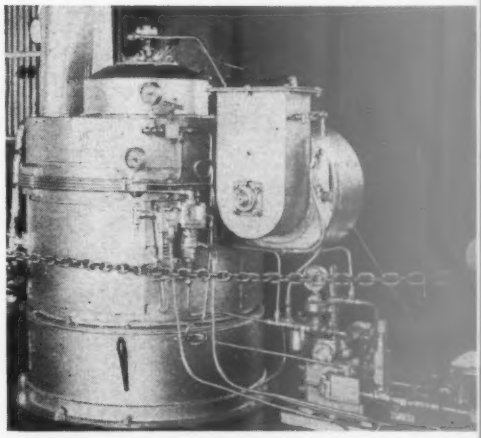
Barge No. 3724 is of standard size and has a draft of from 2 to 4 ft, depending on the loading. It is propelled by a 175-hp outboard propelling unit of a type utilized during World War II to propel supply barges to the beaches during military invasions.

EXCLUSIVE

The after portion of the barge deck is covered by a 24-ft by 16-ft by 8-ft galvanized corrugated iron building, which has large doors opening toward the bow. Housed within this building are the control wheel, hand tools, work benches, paraffin scraping tools, wire line hoist, and a 40-hp steam generating unit, which provides 600-psi steam for melting paraffin deposition in flow lines.

Immediately forward of this building is open deck working space where the long strings of wire line tools are as-





▲ This automatic steam generating unit produces 600-psi working steam pressure in three minutes from cold water and makes 1100 lb of steam an hour (40-hp).

◀ Paraffin barge moored to a Gulf Refining Company oil well in Timbalier Bay, Louisiana.

sembled and broken down. This space can also be used to transport materials and supplies on occasion.

On either side of this working space are two 250-gal horizontal cylindrical tanks. One tank is used to store fuel for the steam generating unit*, the other is used for storing waste oils recovered when bleeding pressure from wellhead connections. This latter feature was provided to prevent pollution of the bays. Within the hull of the barge is a 26-bbl fresh water storage compartment, which is also piped to the steam unit. These tanks permit several days' operation without refueling.

*Vapor-Clorkson Tex-Steamer.

On the bow of the barge are two vertical wooden-lined steel bumpers spaced 3 ft apart to fit against the standard well guards used by Gulf Refining Company. There are also two 16-ft spuds used to hold the barge in position on location. They are situated on diagonally opposite corners of the barge and are operated with individual hand hoists.

Typical Treating Operation

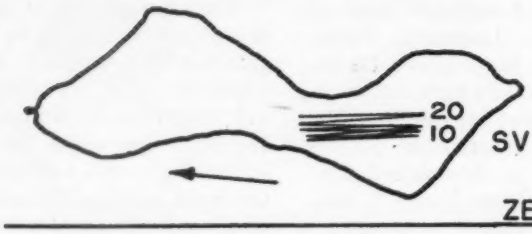
In a typical paraffin-treating operation the barge is moored with the bow resting against a well guard. A string of paraffin scraping tools is assembled on the open deck of the barge. This string consists of paraffin knife, sinker bars, and bumper jars. These tools are fastened to the reel of wire line and lowered into the well through a lubricator that is fastened to the top of the Christmas tree. The paraffin deposited in the tubing is then removed by raising and lowering the cutting knife by means of a small gasoline-engine-driven wire line hoist.

After the paraffin in the tubing is removed, steps are taken to clean the flow line. The steam unit is connected to the flow line and placed in service. From cold water the steamer develops from 100 to 600 psi working pressure in approximately three minutes. Once started, automatic controls take over, controlling the steam output according to demand.

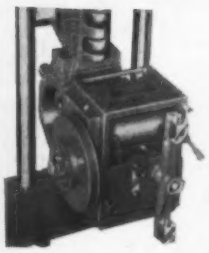
The heat of the steam raises the temperature of the oil flowing through the flow line, which, in turn, melts the paraffin deposited on the internal walls of the flow line, thus permitting it to be carried on to the tank battery in the flow stream.

The frequency of individual flow line treating varies from two weeks to two months, depending on the well. Its importance is readily apparent when it is realized that a suspension of the treatment would necessitate the removal of the flow line for costly mechanical paraffin removal. * * *

DETECT STANDING VALVE LEAK with J-F DYNAMOMETER



Increase in Load Shows Standing Valve Leak in Just 20 Seconds!



The load curve above is based on an actual J-F Dynamometer test made on a producing well. To make this test, the pumping unit is stopped on the downstroke after the traveling valve has opened. If the standing valve holds, the load remains constant. If the standing valve leaks, the load on the Dynamometer will increase within 20 seconds (as shown above), because not only the weight of the sucker rods is measured, but also a part of the fluid load.

OTHER J-F DYNAMOMETER TESTS PROVIDE VITAL FACTS TO HELP YOU

- Detect poor counterbalance
- Stop pulling "green" pumps
- Increase production efficiency
- Reduce sucker rod failures
- Select proper size equipment
- Establish operational control

VALUABLE INFORMATION

Here are two bulletins you can use. One describes the J-F Dynamometer and how it operates. The other explains the instrument's use in checking pumps. Call or write for your copies.

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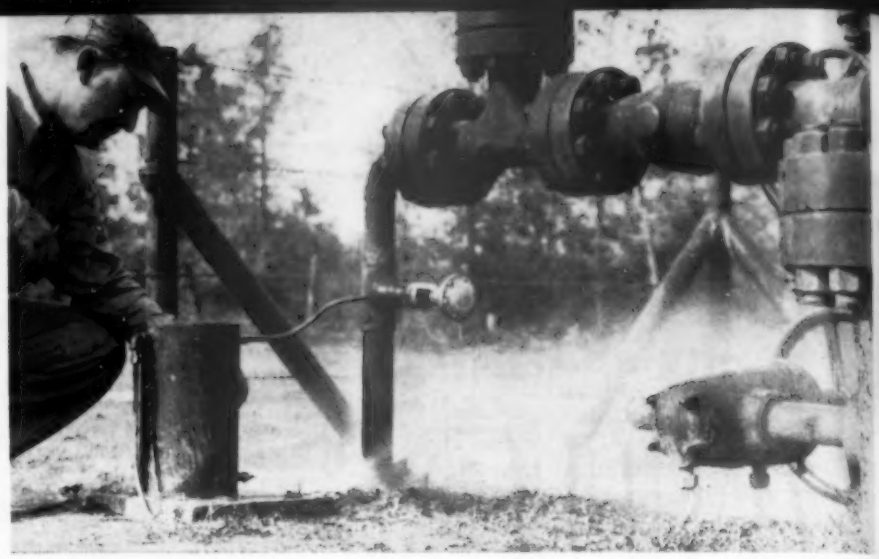
▲ Plastic bottles are used to take liquid samples from drips. The samples are tested for iron content to determine the extent of corrosion



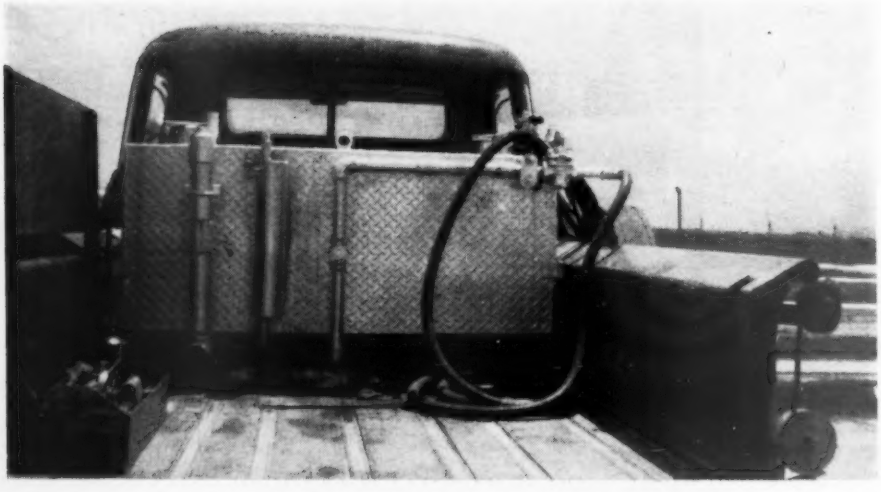
▲ Drips should be blown daily to prevent the accumulation of water in gas supply lines to high pressure inhibitor injection pumps

Jack L. Wiggins
Consulting Engineer

P 432.611

Corrosion Control in Texas Gas Fields

▼ An ammonia tank is shown here installed in the bed of a pick-up truck. It is used to transport ammonia from the warehouse to the well. Brass fittings are avoided and the gage glass on the tank is protected by a swinging cover. The tank is equipped with regulators and safety pressure valves



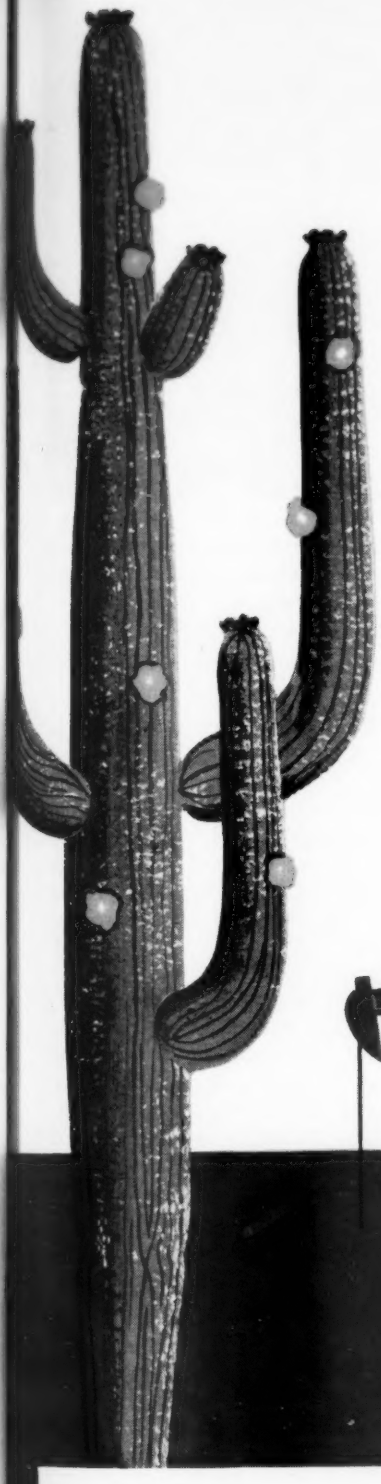
CORROSION of oil and gas equipment offers a challenge to many who are engaged in countering its costly effects. Not only does corrosion result in the loss of material and equipment, it also appears as a continual threat in gas areas where line blowouts and other failures disrupt service, close down production, and halt delivery during critical winter months. This threat exists in both field gathering lines and production equipment, and many companies are steadily engaged in the detection and prevention of the damaging effects of corrosion and corrosive moistures that collect in lines and installations, and destroy thousands of dollars worth of equipment every month.

In the Carthage field in East Texas, an entire gathering system is being gradually converted from a micarta sleeve and washer protected line to an anodic protected line. Each connection that previously had been fittted with micarta insulating material, is now being uncovered and equipped with metal jumpers that allow electric current to flow over the insulating material.

While these preventive measures are being perfected, a constant search is underway in this same gathering system to locate highly corroded sections of gas lines which, in some instances, are carrying pressures of 2500 psi. Therefore, it becomes necessary to uncover sections of field lines that engineers' contour maps show to be low in elevation. Water often collects in these low areas, and it is axiomatic that where water is present corrosion is accelerated. The pieces of line that have been cut out with acetylene torches are

EXCLUSIVE

XUM



Block Buster!

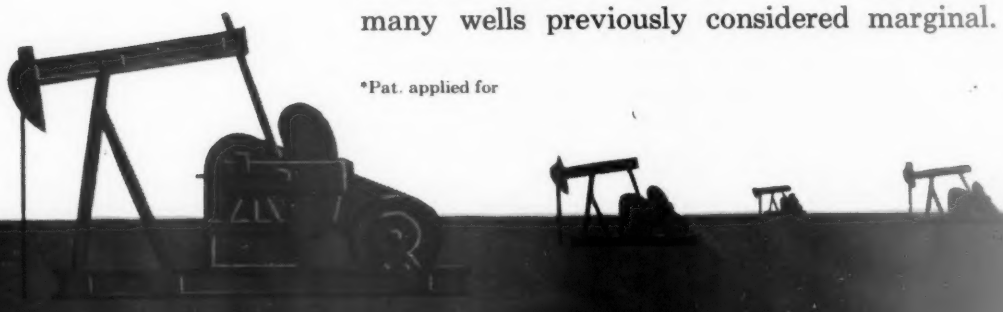
ATPET 931 revives water-damaged wells

Water blocks which have cut off or reduced production are now being removed at low cost by the use of ATPET 931, a unique interfacial tension depressant made by Atlas Powder Company. A process* developed by Stanolind Oil & Gas Company makes use of this chemical to stimulate old wells, to restore dead wells, and to complete new wells that are subject to water damage.

This process consists of injecting field crude containing about 1% ATPET 931 into the oil formation. By reducing the interfacial tension between oil and water practically to zero, this new chemical breaks water blocks and permits oil flow through the strata.

Payout is fast. Amortization time is measured in days . . . instead of months. The process costs exceptionally little, and permits economical stimulation of many wells previously considered marginal.

*Pat. applied for



ATPET 931 is non-ionic; gives excellent performance in the presence of oil field waters and brines, and has little tendency to plate out on solid surfaces. Write your nearest Atlas office for samples and further information.

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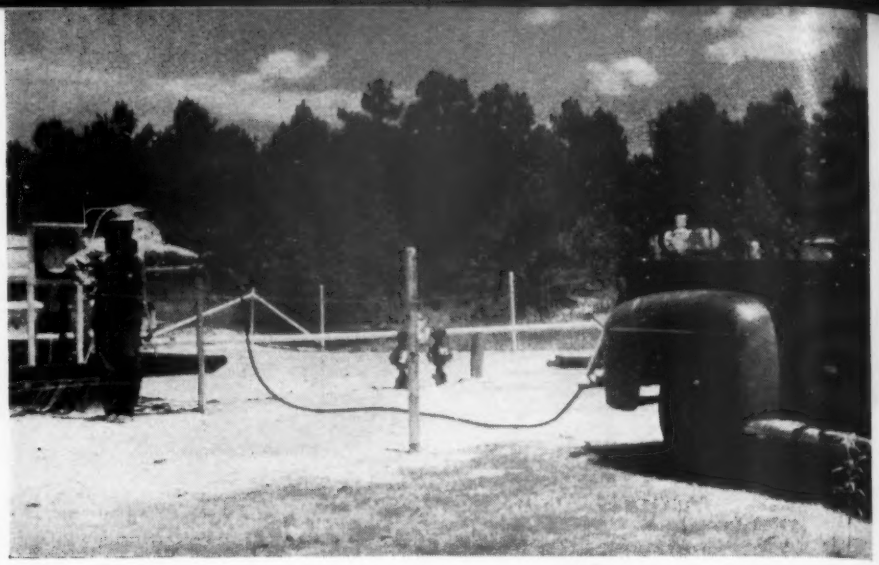
Vertical lubricators of this type are used in the Carthage gas field for the injection of liquid corrosion inhibitors



Corrosion inhibitor equipment is portable on this operation, and one pump serves several leases

removed, repaired, or replaced with new line, and re-welded into position. In other instances gamma-ray pictures are taken to determine the extent of corrosion inside the line.

Measurement of Inhibitor Effectiveness

Since it is nearly imperative in safe operation to know the rate of corrosion, many methods of measuring corrosive activity have been developed. Tests are continually being made, not only to measure corrosion but to measure the effectiveness of corrosion inhibitors that are being applied to the system susceptible to damage. Obviously, this measurement would be necessary to determine which type of inhibitor is most effective in each situation.

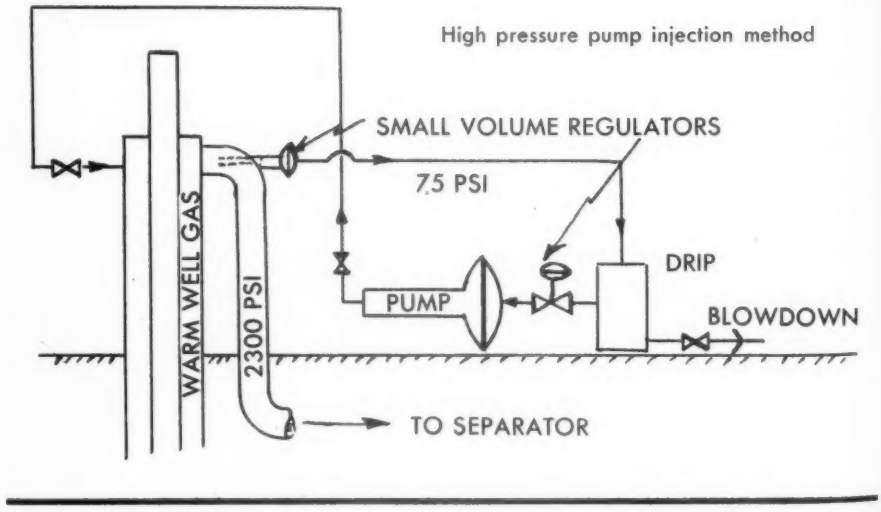
The use of metal tabs or coupons is generally employed to arrive at the rate of corrosion in gas lines at any given point. These metal coupons are placed in the gas stream at designated locations, having previously been carefully weighed. They are allowed to remain in the corrosive stream for a definite length of time; then they are removed and weighed again. The loss of metal from the coupon is an indication of the degree of corrosion taking place in the metal of the gas line at that point. Or, if an inhibitor is being added to the corrosive stream, then the loss of weight in the coupons will furnish some data on which to estimate the effectiveness of the inhibitor.

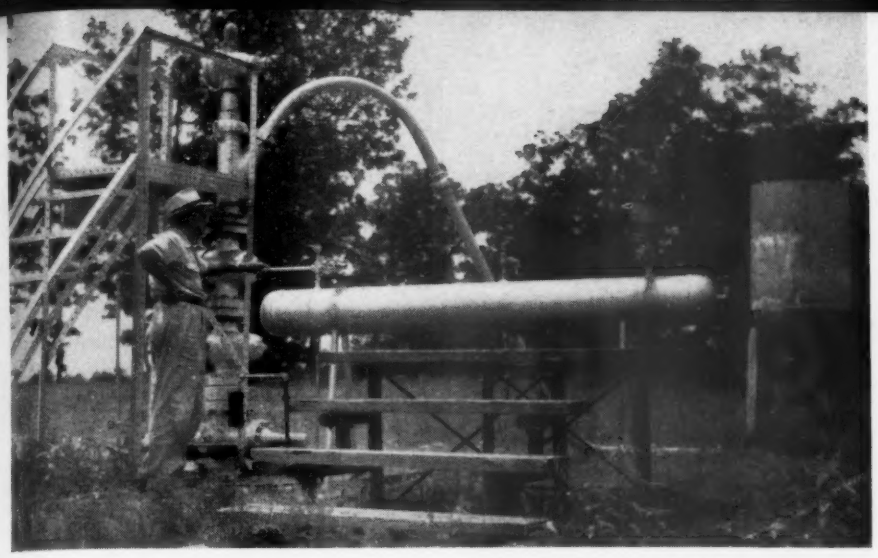
Metal tabs or coupons may be installed by a patented device that permits the inserting and removal of coupons in a line while it is under pressure, or they may be installed in shop-made holders, which are attached to bull-plugs that screw on nipples welded into the line.

Another method of determining the extent of corrosion in a system is the measurement of the iron or metal content of liquid condensate that has been removed from the system. A comparison of this iron content to the original iron content of the formation reveals the amount of metal that has been removed from the system by corrosion and deposited in the condensate. These iron content measurements may be used also to chart the effectiveness of inhibitors.

Testing iron content of condensate samples may be done several ways, but basically two methods are followed: Iron titration tests, or the utilization of a combination photo-electrical chemical device that gives a reading in parts per million on a light-cell gage. This latter device eliminates human error in evaluating the solution color, which, in essence, determines iron content. One such device will determine the amount of iron, phosphates (total and polyphosphates), silica, alumina, oxygen, sulfates, and chromates that are present in the sample. Kits of reagents are supplied with each type of test desired, complete with instructions for use.

In some high pressure gas producing areas, titration tests are being made weekly by field men to determine the extent of corrosion existing in lines. The results of the titration tests determine when inhibitors should be added and also indicate the effectiveness of the entire corrosion inhibition program. In some instances samples are taken and tested immediately in the field. Other practices direct the samples to laboratories, and in this event it is sometimes





▲ Sodium bicarbonate mixed in the concrete tank in the background is placed into this horizontal lubricator for corrosion mitigation in East Texas. Steps and a platform facilitate filling the lubricator

Stick inhibitor material is used in many Texas gas fields to prevent corrosion ▶

convenient and more practical to collect the samples in plastic bottles.

Injection of Liquid Corrosion Inhibitors

Corrosion inhibitors in liquid form are being injected into gas wells in the Woodlawn area, north of Marshall, Texas, by use of a diaphragm pump capable of opposing high pressures. The pump will place the inhibitor in the gas stream against full well pressure of 2300 lb, thereby eliminating the use of lubricators or solid stick injection.

This method of corrosion inhibition requires a constant supply of gas pressure, as does any diaphragm pump. Supply gas will form hydrates and freeze when reduced from certain high pressures to 30 psi required for operation of the diaphragm pump. Preventive measures may be taken to retard this freezing and insure a constant gas supply.

One widely used method of preventing supply gas failure because of freezing is the application of gas well heat at the point of initial pressure reduction. This application of heat is made through the use of a small high-pressure regulator that utilizes the heat of the gas stream. The regulator is equipped with a long nozzle that extends into the center of the warm gas stream. Expansion from high to low pressure is accomplished by an orifice in the tip of the nozzle where heat to prevent freezing is available from the stream of gas itself. Additional regulators attached to the diaphragm pump further reduce supply pressure until operating pressure is reached.

This method of inhibitor injection lends itself to controlled amounts, however small, and a very slow rate of injection is possible. In the Woodlawn area, liquid inhibitors are being added by a pump that operates at one stroke per minute.

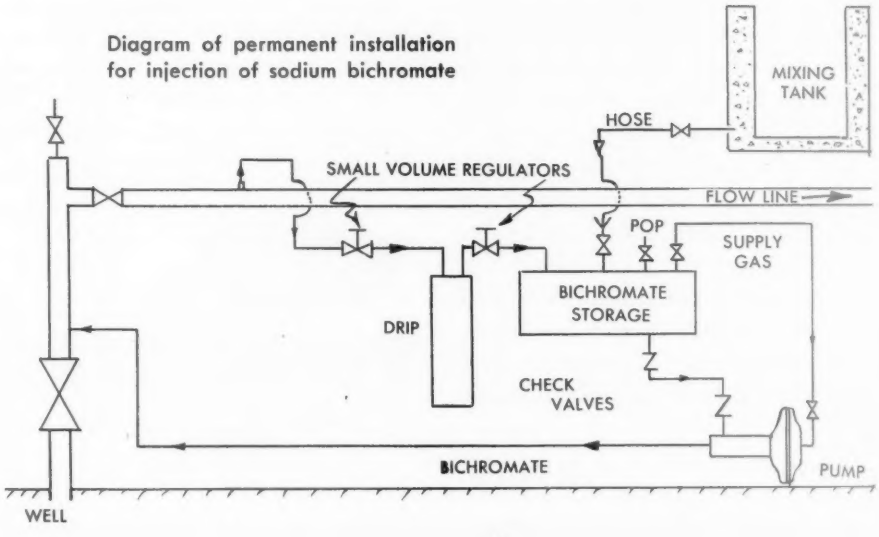
Another method of preventing the freezing of supply gas is the elimination of moisture from the gas by installation of a shop-made drip. Water in gas supply lines tends to cause hydrate formation and causes pump failures with attendant interruption of corrosion treatment. The drip should be blown down daily to dispose of accumulated moisture.

Portable Injection Equipment

Off-shore wells on the Gulf Coast are also served with a corrosion inhibitor by a unique method. A diaphragm pump with attached high pressure gas hoses is installed in a small craft, and pumpers pilot the boat from well to well, anchoring it and attaching the hoses to the wellhead for supply gas to operate the diaphragm pump and to inject a corrosion inhibitor. This practice eliminates the necessity of installing high-priced equipment on off-shore leases where it is continually subjected to the deterioration of salt water.

Around Bay City, Texas, wells are treated with anhydrous ammonia through an arrangement whereby the ammonia is transferred to the well in a tank mounted permanently in a pick-up truck. The ammonia is transferred to the lease supply tank by attaching a hose to the wellhead and using a regulated pressure to force the ammonia into the lease tank from the truck tank.

Diagram of permanent installation for injection of sodium bichromate



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Since ammonia reacts with brass, all fittings must be steel or iron. Also, ammonia may become a safety hazard when handled. Its fumes are pungent and dangerous. A completely safe method has been devised whereby the liquid ammonia is unloaded from dock to truck. This unloading is accomplished by fitting the dock drum with a long spigot that has been screwed into the head opening, then placing a slight, regulated pressure in the drum, forcing the ammonia out through the spigot into truck tank.

The truck tank is equipped with a sight glass and a calibration scale which reveals the amount of ammonia in the tank. The sight glass is protected by a swinging guard which is kept closed except when filling the tank. Only enough ammonia is placed in the tank to meet the requirements of the leases, so that no appreciable amounts of ammonia remain in the truck container.

Operators handling ammonia inhibitors should be instructed in their use in order to insure safe operations.

In other gas areas, high pressure diaphragm pumps are loaded periodically into truck beds and hauled to leases which require the injection of corrosion inhibitors. With the use of long, high-pressure hoses the gas for operating the pumps is brought from the wellhead and reduced with several regulators. A predetermined amount of inhibitor liquid is then forced into the well. The hoses and fittings are removed, taken to another lease requiring injection of inhibitors, and so on, until all of the wells requiring service have been visited. This arrangement eliminates the duplication of equipment at each lease, making it possible for one diaphragm pump to serve several wells.

Permanent Injection Equipment

In some areas it has been found that constant injection is necessary to prevent corrosion, and on these locations there have been installed permanent installations for the injection of either solid or liquid corrosion inhibitors. One such installation in East Texas was built for the injection of sodium bichromate as an inhibitor. Sodium bichromate is also an inhibitor that must be handled with care. It attacks the skin and membranes of the body and should not be breathed. It is a powder and must be poured into vats and mixed with water. Operators using sodium bichromate should be instructed in safe procedure.

After the solution is mixed and prepared it is moved to a pressure tank by gravity flow, since the mixing vat is built higher than the pressure tank. This pressure tank contains not only the liquid, but also serves as a volume

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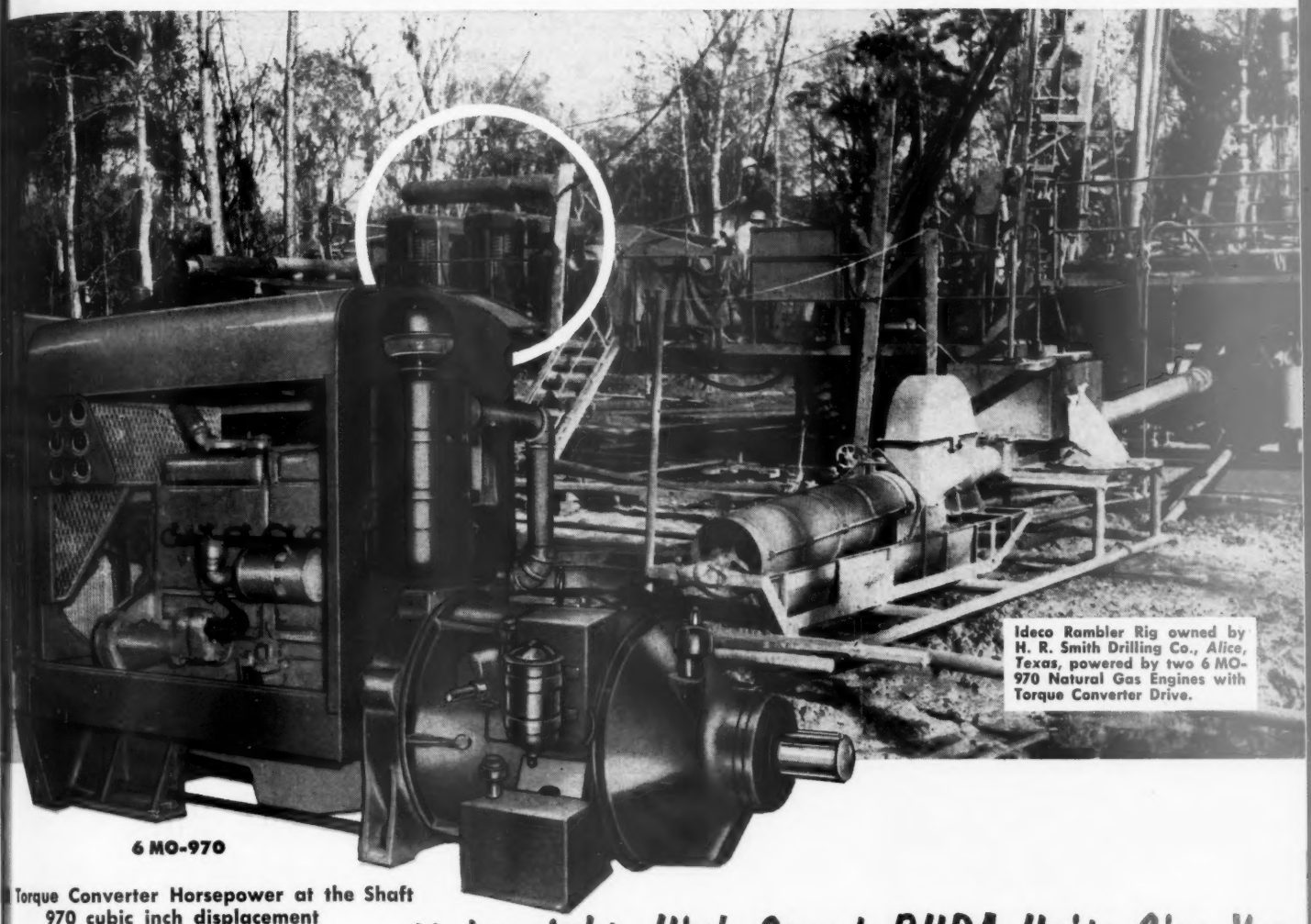

Ideco Rambler Rig owned by H. R. Smith Drilling Co., *Alice, Texas*, powered by two 6 MO-970 Natural Gas Engines with Torque Converter Drive.

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tank for diaphragm pump supply gas that has been taken from the gas line and reduced with small-volume regulators. Ball and seat check valves on the discharge line of the diaphragm pump are protected from the corrosive effects of the sodium bichromate by a water-resistant grease which is applied through a grease fitting.

Bichromate is also injected by use of a horizontal lubricator. The mixed inhibitor is run to a lubricator after it has been mixed in a concrete vat. Wooden steps and a platform faciliate the addition of the inhibitor.

A vertical lubricator is used for corrosion inhibitor injection in the Carthage field. Liquid is added to the lubricator after the gas pressure has been released.

Solid Inhibitor Injection Equipment

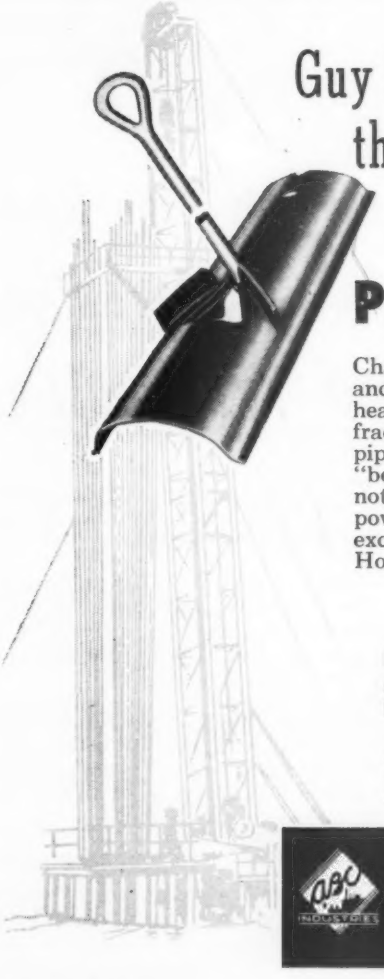
Gas wells in the Bay City area are sometimes treated with solid sticks of corrosion inhibitor. The sticks are dropped through a special head into the tubing and will dissolve as they fall by gravity. With this type of treatment the wellhead must be equipped with an installation that acts as a liquid lubricator. Stick inhibitors are added daily in varying number depending on the requirements of treatment for the particular installation involved. It was found that evenly spaced injection of solid sticks was more effective in this area than periodic injection. In other words, better protection resulted from one stick every day than five sticks every five days.

Inhibitors

A survey of the inhibitor market shows that a dozen different manufacturers are furnishing corrosion inhibitors to the industry under many different trade names. In many areas formaldehyde, potassium dichromate or sodium bichromate are used as corrosion inhibitors, while in other areas trade-name inhibitors are used almost exclusively. Many oil company engineers are making a systematic survey of inhibitors to determine which will be most effective in particular areas.

Corrosion inhibition apparently is coming to be an accepted part of gas production in many areas, and the operation of testing equipment, injection equipment, and the handling of inhibitors has come to be a part of the present day duties of field operators and pumpers.

It is also evident that corrosion inhibition is a vital problem in gas areas of Texas, although methods of treatment and injection may differ widely. ★



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WORKHORSE of the marshes

MOST interesting of workhorses in the bayou and marshland located oil fields of South Louisiana are the paraffin barges of Gulf Refining Company. These self-propelled units, 60-ft long, 20-ft wide, and 5-ft deep, are operated by two or three man crews who perform such jobs as scraping paraffin from well tubing, steaming paraffin from flow lines, cleaning and painting Christmas trees, running bottom hole pressure instruments and safety valves, and other wire line work.

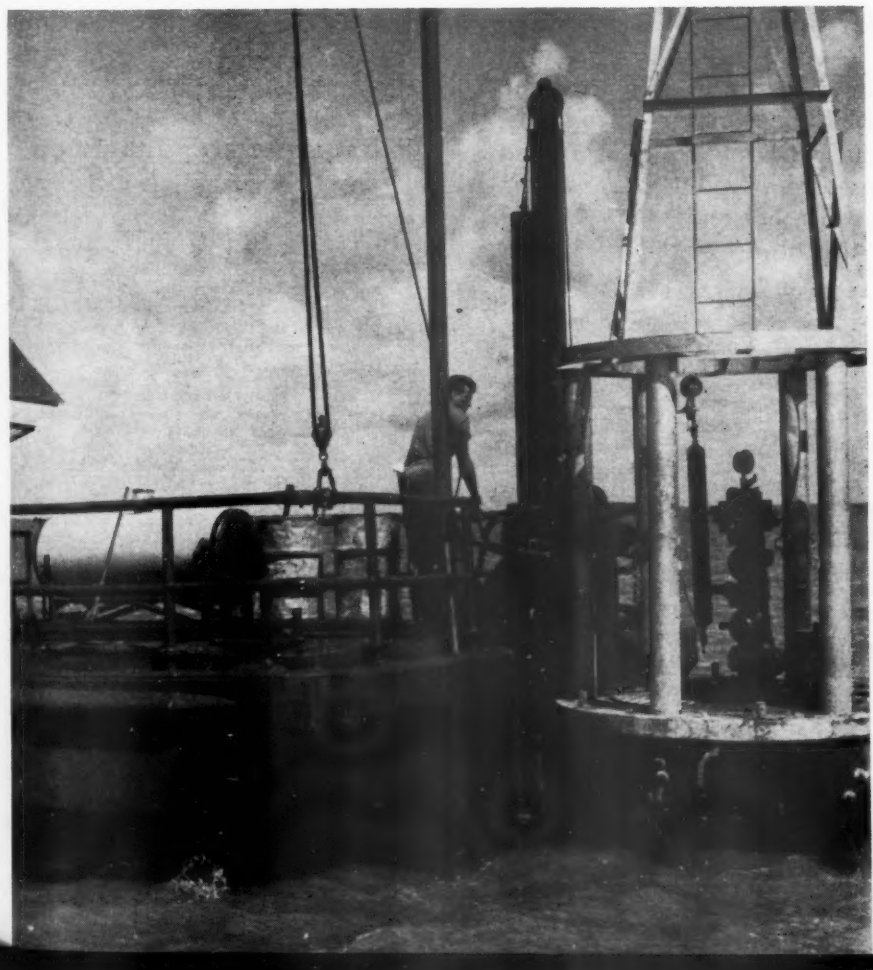
Typical of these operations is that of Barge No. 3724 in Gulf's Timbalier Bay field, approximately 90 miles south and west of New Orleans in LaFourche Parish. This field is supplied from a dock at Leesville, Louisiana, from which the paraffin barge crews travel by taxi boat to the field each morning and return each evening along with other field operating personnel.

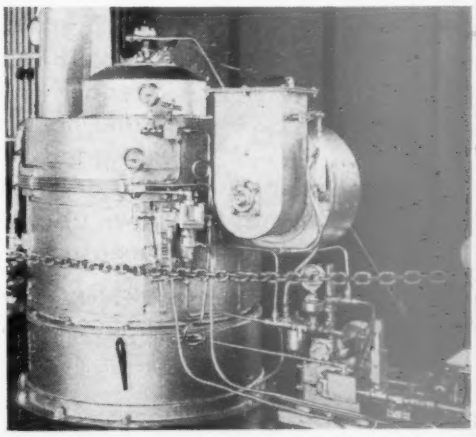
Barge No. 3724 is of standard size and has a draft of from 2 to 4 ft, depending on the loading. It is propelled by a 175-hp outboard propelling unit of a type utilized during World War II to propel supply barges to the beaches during military invasions.

EXCLUSIVE

The after portion of the barge deck is covered by a 24-ft by 16-ft by 8-ft galvanized corrugated iron building, which has large doors opening toward the bow. Housed within this building are the control wheel, hand tools, work benches, paraffin scraping tools, wire line hoist, and a 40-hp steam generating unit, which provides 600-psi steam for melting paraffin deposition in flow lines.

Immediately forward of this building is open deck working space where the long strings of wire line tools are as-





▲ This automatic steam generating unit produces 600-psi working steam pressure in three minutes from cold water and makes 1100 lb of steam an hour (40-hp).

◀ Paraffin barge moored to a Gulf Refining Company oil well in Timbalier Bay, Louisiana.

sembled and broken down. This space can also be used to transport materials and supplies on occasion.

On either side of this working space are two 250-gal horizontal cylindrical tanks. One tank is used to store fuel for the steam generating unit*, the other is used for storing waste oils recovered when bleeding pressure from wellhead connections. This latter feature was provided to prevent pollution of the bays. Within the hull of the barge is a 26-bbl fresh water storage compartment, which is also piped to the steam unit. These tanks permit several days' operation without refueling.

*Vapor-Clorkson Tex-Steamer.

On the bow of the barge are two vertical wooden-lined steel bumpers spaced 3 ft apart to fit against the standard well guards used by Gulf Refining Company. There are also two 16-ft spuds used to hold the barge in position on location. They are situated on diagonally opposite corners of the barge and are operated with individual hand hoists.

Typical Treating Operation

In a typical paraffin-treating operation the barge is moored with the bow resting against a well guard. A string of paraffin scraping tools is assembled on the open deck of the barge. This string consists of paraffin knife, sinker bars, and bumper jars. These tools are fastened to the reel of wire line and lowered into the well through a lubricator that is fastened to the top of the Christmas tree. The paraffin deposited in the tubing is then removed by raising and lowering the cutting knife by means of a small gasoline-engine-driven wire line hoist.

After the paraffin in the tubing is removed, steps are taken to clean the flow line. The steam unit is connected to the flow line and placed in service. From cold water the steamer develops from 100 to 600 psi working pressure in approximately three minutes. Once started, automatic controls take over, controlling the steam output according to demand.

The heat of the steam raises the temperature of the oil flowing through the flow line, which, in turn, melts the paraffin deposited on the internal walls of the flow line, thus permitting it to be carried on to the tank battery in the flow stream.

The frequency of individual flow line treating varies from two weeks to two months, depending on the well. Its importance is readily apparent when it is realized that a suspension of the treatment would necessitate the removal of the flow line for costly mechanical paraffin removal. * * *

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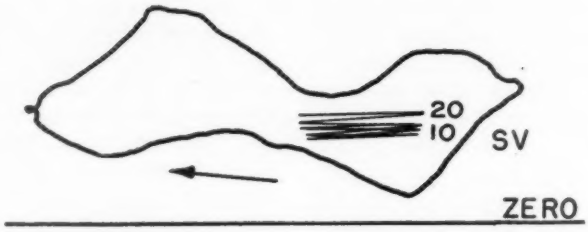
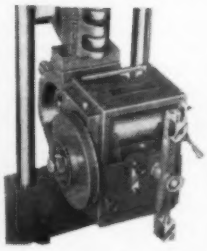


Increase in Load Shows Standing Valve Leak in Just 20 Seconds!



The load curve above is based on an actual J-F Dynamometer test made on a producing well. To make this test, the pumping unit is stopped on the downstroke after the traveling valve has opened. If the standing valve holds, the load remains constant. If the standing valve leaks, the load on the Dynamometer will increase within 20 seconds (as shown above), because not only the weight of the sucker rods is measured, but also a part of the fluid load.

OTHER J-F DYNAMOMETER TESTS PROVIDE VITAL FACTS TO HELP YOU

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Montana Bureau of Mines Opens Billings Field Station

Montana Bureau of Mines and Geology has established a new petroleum field station in Billings as a pemanent respository for a collection of cuttings and core samples from wells in that state.

Materials of the Montana School of Mines in Butte augmented by donations from oil companies have formed the basic collection of the station. The United States Geological Survey has also provided materials on a long-term loan basis. Samples, as received from Montana's new wells as requested by the state Oil and Gas Conservation Commission, will be added to the field station's collection.

Formational material has been leased voluntarily by the operators and is available for inspection in the field station any week day from 8 to 5. A catalog listing the wells, their location and footage, is made available to anyone writing to the Petroleum Field Station, Montana Bureau of Mines and Geology, Box 405, Billings.

Operation of the field station is under the direction of O. D. Blake, and is under the jurisdiction of J. R. Van Pelt.

SEALED TYPE "I" BOWEN JAR SAFETY JOINTS

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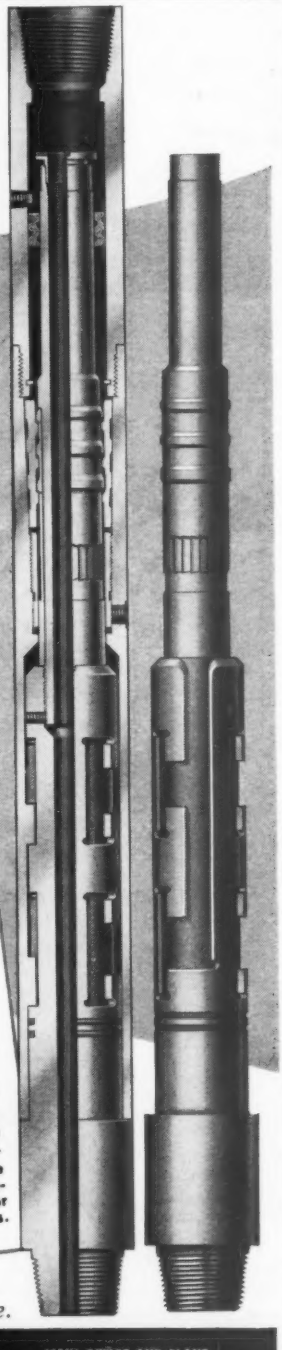
Constant Tripping Tonnage



SEALED TYPE "I" BOWEN JAR SAFETY JOINTS are filled with oil and sealed top and bottom. The Sealed construction enables the tool to transmit circulating fluid at any pressure and prevents any contact between the well fluid and the working parts of the tool. With this arrangement, the moving parts work in a bath of oil.

SEALED TYPE "I" BOWEN JAR SAFETY JOINTS are compact combination units designed to provide the services of both rotary jars and safety joints. They are installed as safety devices in strings during testing, coring, reaming, drilling, sidetracking and washing over operations and are also used during fishing operations. At the will of the operator they will either deliver heavy upward or downward blows against a stuck string or fish — or they can be disengaged to salvage all the string that is above them. Besides sealed lubrication they feature:

ADJUSTABILITY IN THE HOLE *You can increase the tripping tonnage without coming out of the hole.*

FULL OPENING *Oversize circulation hole permits use of wire line tools and allows passage of large volumes of fluid.*

OUTSTANDING ADVANTAGES AS A JAR

The tripping mechanism in the SEALED TYPE "I" BOWEN JAR SAFETY JOINTS is a straight pull mechanical type.

Torque free operation eliminates any aggravating tendency to release fishing tools, reduces equipment wear, and avoids hazards.

Because the tripping mechanism is purely mechanical, heavy blows can be struck despite packing failures or high temperatures and the same heavy blows will be delivered regardless of whether the string is elevated slowly or rapidly.

The tripping pull can be increased while the tool is in the hole or the tripping pull can be either increased or decreased while the complete tool or just the Bowl Assembly is at the surface. After considerable use, the wearing parts in SEALED TYPE "I" BOWEN JAR SAFETY JOINTS can be replaced easily and economically and the tool will regain all the properties of a new one.

OUTSTANDING ADVANTAGES AS A SAFETY JOINT

SEALED TYPE "I" BOWEN JAR SAFETY JOINTS will deliver the full torque capacity of the string in either direction.

At the will of the operator, the Bowl Assembly can be separated from the Main Mandrel Assembly of the tool to salvage all of the string that is above it.

Later the Bowl Assembly can be reengaged with the Main Mandrel Assembly in the hole for subsequent recovery operations.

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Oil in Western Australia Sparks New Guinea, Papua Exploration

As a result of the oil showing at Rough Range, Western Australia, late in 1953 there has been renewed interest by Australian syndicates in the search for oil in Papua and New Guinea. Such reaction was not based on any geological relationship between the Western Australian occurrence and the sedimentary basins in Papua and New Guinea but on public optimism fired by reports of the Western Australian strike.

During the past year twelve new petroleum prospecting permit applications were received.

One permit over a rectangular area of 1650 square miles, adjacent to the Dutch New Guinea border and including the middle reaches of the Sepik River, was granted to Enterprise of New Guinea Gold and Petroleum Development N.L. for a period of 12 months.

This company completed a preliminary geological survey of three months duration over portion of their permit area in 1954.

Australasian Petroleum Company Limited and Island Exploration Company Limited, both owned by British Petroleum, Standard Vacuum and Oil Search, an Australian concern, still dominate petroleum exploration in this region. Their combined holdings under permit aggregate 34,844 square miles in the major sedimentary basin of southwestern Papua.

Geological surveys, reconnaissance and detail, have occupied 24 party months. Palaeontological, photogeological, petroleum engineering laboratories have been maintained at Port Moresby headquarters. Two seismic parties, one operating with helicopters and one gravity party have been in the field throughout the year.

Three wells are now in progress in this area .

After installing a high pressure wellhead on the Omati test well drill pipe was recovered to a depth of 11,778 ft. A window was cut in the 6⅝-in. casing at 11,686 ft and the hole redrilled to a depth of 13,780 ft. A 4¼-in. liner was then set at 13,774 ft and hung at 11,470 ft. Tests are now being conducted through perforations to evaluate a gas show at 13,743 ft.

A second test well was spudded in about two miles from the No. 1 well and was last reported at a depth of 7,875 ft, 13⅜-in. casing having been set at 5663 ft.

A camp is being built on the Aramia River in preparation for a test well, and a 7-mile road is under construction to a test site near the Kuru Creek.

Formation sampling takes a new twist in air drilling. Cuttings are brought from the bottom of the hole to surface in about 30 seconds.

R. B. Reed, president of Reed Drilling Company, Inc., and contractor for the test, inspects the bit which cut the first 822 ft of hole. Teeth and cone bearings showed little wear.

Outlook for air drilling brighter as formation water problems are overcome by high volumes in northeastern Oklahoma test

AIR DRILLING *from top to bottom*

C. R. Graham
Field Editor

DRILLED with air from rathole to diamond core, a Tulsa, Oklahoma, test conducted in late April literally blew away many of the misconceptions and questions surrounding the process. Keener Oil Company's Osage A No. 1 water injection well was drilled by the Reed Drilling Company, Inc., with the joint participation of Schramm, Inc., Drilling and Service, Foxboro, and Eastman Oil Well Survey Company for the sole purpose of exploring the possibilities of air as a circulating fluid in the Oklahoma area.

Several favorable conclusions were drawn from the test. It was demonstrated that: (1) Areas with highly com-

EXCLUSIVE

pacted formations normally considered hard drilling could be drilled more economically with compressed air, (2) Bit life and penetration rates can be improved by the use of large volumes of air, (3) 1800 cfm of air volume is sufficient to handle formations making considerable amounts of water, (4) Coring with diamond bits and air avoids contamination commonly caused by mud and water, and (5) Overall economy to the operator and the contractor is substantially improved.

Although air drilling is being conducted successfully in Pennsylvania, the San Juan Basin of New Mexico, Colorado, and California to penetrate extremely hard formations, its possibilities in Oklahoma virtually were unknown.

The well, located in southeastern Osage County on the outskirts of Tulsa, was drilled in the Flat Rock Pool and bottomed in the Bartlesville sand at 1569 ft. It will be used in Keener Oil Company's waterflood project as an injection well.

Air used in drilling was provided by three Schramm compressors, each with a rated capacity of 600 cfm. They were mounted individually on rubber-tired trailers for simplified moving.

A Unit rig U-34 drawworks and Lee C. Moore 96-ft trailer mast was used to drill the well. As only light drilling weights were suggested for the test, two to four 6¼-in. drill collars were used with the 4½-in. drilling string. Air from the three compressors was manifolded into a 4-in. line to the 4-in. standpipe and standard rotary hose.

To provide permanent recording of the air pressure, and supplementing the regular air gage mounted near the weight indicator, a Foxboro pressure recorder was installed in the doghouse. Eastman provided a logging instrument to aid in correlating the drilling rate with pressure factors. A running record was kept from spudding-in until completion of the well. The data compiled on this test and made available to the industry, will undoubtedly provide a valuable tool for future air drilling not only in Oklahoma but elsewhere.

Water courses in the bits were removed by acetylene torch to permit maximum air flow, thereby minimizing down-hole pressure.

Every step in the drilling process was varied to determine optimum conditions. Rotary speed was slowed and accelerated, drilling weights were changed, pressures and volumes were fluctuated, and the effects of these changes were recorded.

Drilling wellhead assembly was fabricated especially for the test. The improvised "pack-off" provided a flexible rubber grip around the kelly joint to channel air and cuttings returned from the bottom of the hole out a 6-in. exhaust pipe. This exhaust deposited cuttings about 40 ft from the rig.

Mud pits and slush pumps that characterize regular rotary operation were conspicuous by their absence.

The well was spudded April 20 at 6:55 p.m. with 8⅝-in. casing set at a depth of 44 ft. Water was hauled to the location to cement the casing string.

On the following day, at 2:20 p.m. drilling began with a 7⅞-in. soft-to-medium formation bit.

First bit was pulled out of the hole after reaching a depth of 822 ft, drilling at a rate of about 66 ft per hour. On inspection, the bit was found to be in good shape. Cone bearings and teeth showed little wear. Rotary speed for the first 1000 ft varied between 70 and 100 rpm. Only small water sands were encountered; the water caused formation of steam which was ejected at the exhaust. Cuttings in dry formations ranged from a fine dust to dime-size. Samples of all cuttings were taken at the end of the exhaust pipe with a bucket and small seive.

High annular velocity of the air brought cuttings from bottom rapidly. Cuttings were brought from the bottom of the hole to the surface in as little as a half a minute. Ability to bring cuttings to the surface quickly made it possible to clean out the hole in not more than about five minutes prior

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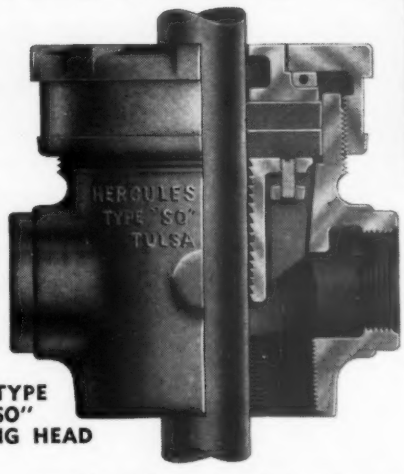

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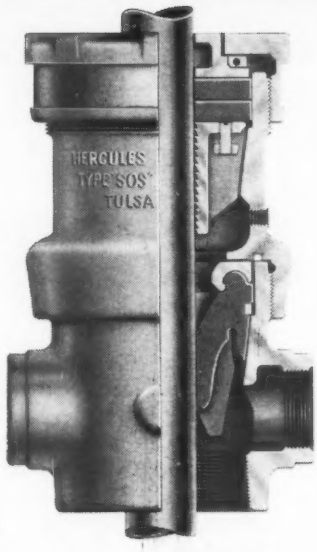

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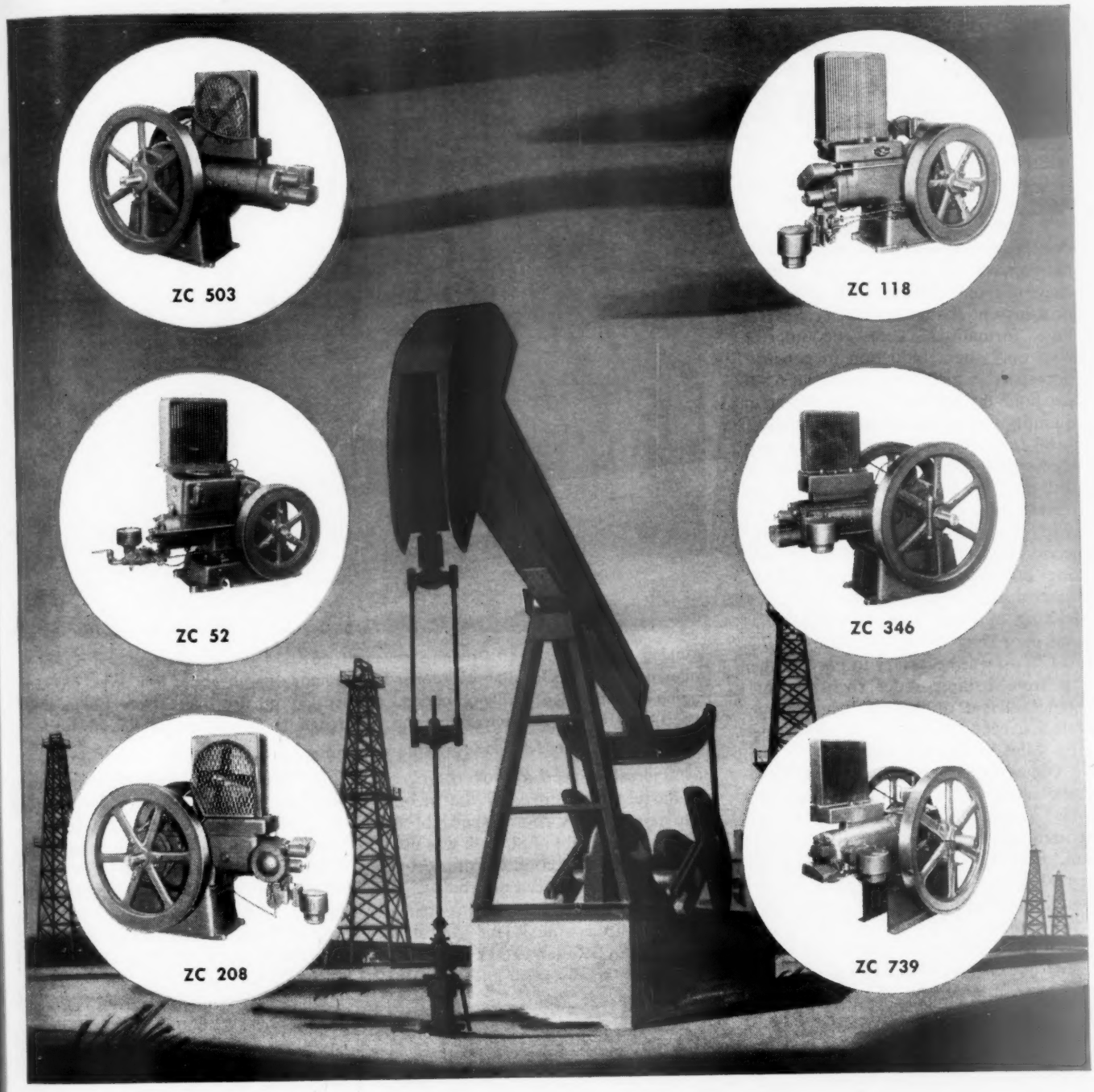

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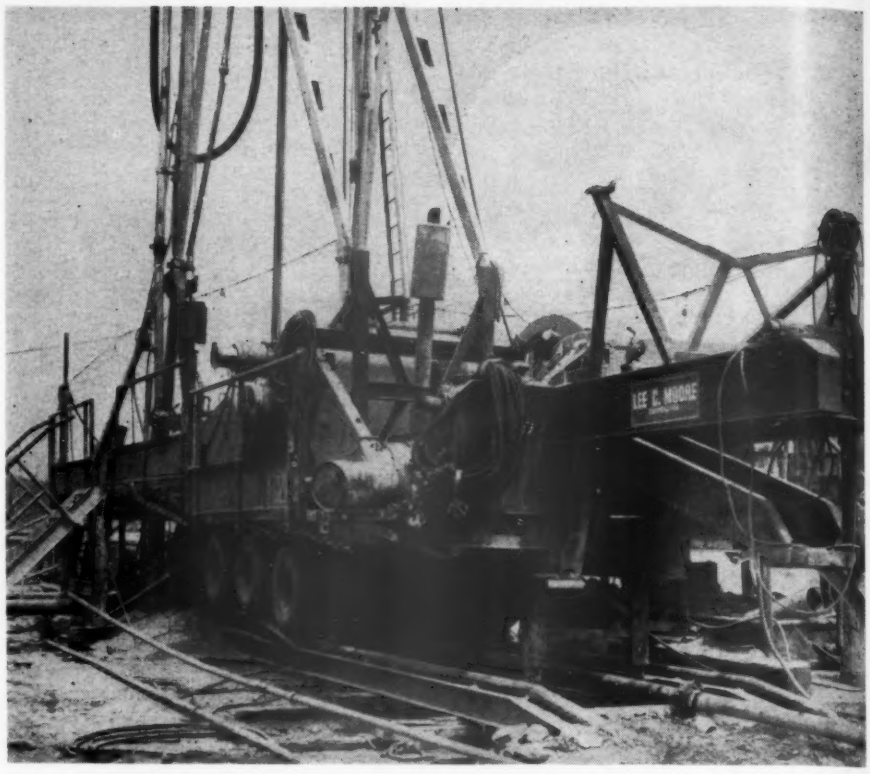
to taking formation samples for correlation and examination. The procedure involved would be to discontinue drilling until the hole was clean and then continue drilling after samples were taken. In conventional drilling practices, from 45 minutes to 1½ hours are required to clean the hole prior to taking an accurate sample.

Air pressure by the compressors under normal operation was fluctuated between 40 and 75 psi, with a volume ranging from 1200 to 1800 cfm with no apparent change in velocity. Several lime formations were encountered, with only slight reduction in penetration speed, which averaged about 65 ft per hour throughout the test. Water in quantity was encountered at a depth of 1180 ft. Considerable experimentation showed that to prevent the sticking of drill pipe, the hole must be either completely dry, blowing out cuttings in chip form, or wet enought, by water injection down the hole, to bring the cuttings out in a slurry. Slight amounts of water deposited mud on the drill pipe. Raising and lowering the drill stem and increasing the air pressure to 170 to 180 psi was necessary to prevent the bit from balling under such circumstances. Heat of the air being circulated exceeded 200 F, complicating the water intrusion problem.

Objective of the test was the Bartlesville sand, which was diamond-cored. Air coring brought most favorable comments from Keener Oil, Drilling and Service, which provided core barrel and bit, and the Earlougher Engineering Company which compiled the core analysis.

Of the two cores taken, the first 49-ft cut recovered only 25 ft of sample. Excessive speed and overfilling of the barrel was blamed for the incomplete recovery. A rotary speed of 80 rpm and bit weight of 8000 lb was used in cutting the first core. On the second core, both rotary speed and bit weight were varied with little apparent change in penetration rate. This variation ranged from 12,000 lb at 75 rpm to 13,000 lb and 100 rpm, and a perfect 30-ft core was returned. The core analysis seemed to indicate that the core had better oil saturation and less water saturation than is common in cable tool or ordinary rotary cores. The diamond bit cut through the shale (upper 16.5 ft of the first core) at a rate of 2 to 3 minutes to the foot. The oil sand was cut at about 1½ minutes to the foot.



"Making hole fast," Reed Drilling's new unit rig U-34 drawworks and Lee C. Moore trailer mast was on location of Keener Oil Company's well about five days, including rigging-up, spudding, drilling, coring, and casing running time. Note cuttings (by wheels) that have collected around the improvised "pack-off" under rig substructure.

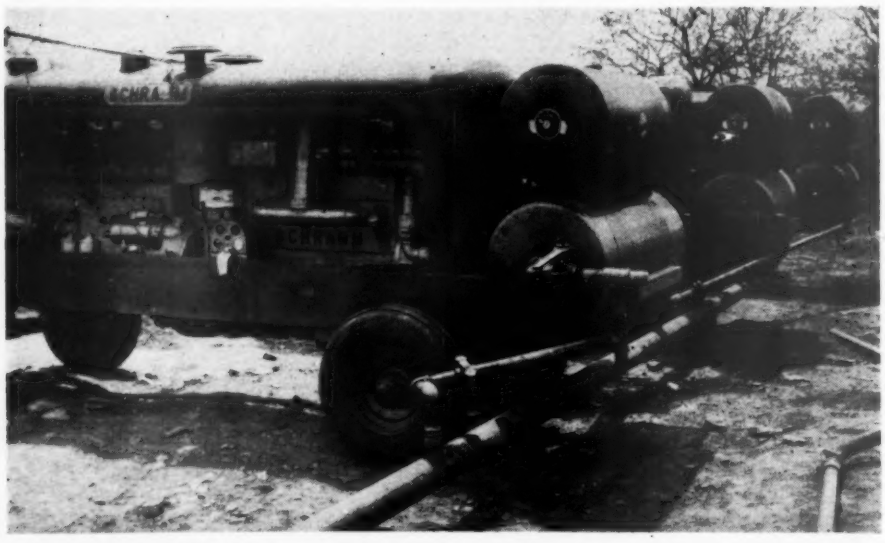
Comment from officials of Drilling and Service suggested that air coring would be applicable under almost any conditions, and especially in this area of northeastern Oklahoma.

The well was finaled at a total depth of 1569 ft. Total time was three days.

The test, which developed through the cooperation of Keener, Reed Drilling, and Clarence L. Boyd, Inc., Schramm distributors for the Tulsa area, was witnessed by hundreds of personnel from other drilling firms, oil companies, suppliers, and manufacturers from Oklahoma and neighboring states.

Implications of those directly associated with the test, was that the interest generated and cooperation received, would suggest many air drilling ventures for the area in the future.

In any case, much good is achieved any time the drilling contractor, producer, manufacturer, and service man come together on common ground with common problems. * * *



Three Schramm 600 cfm compressors provide sufficient air to penetrate water-bearing formations as well as lime and shale in the Tulsa, Oklahoma, test. Drilling with the use of two of the compressors, at 50 psi, proved adequate for much of the drilling. Pressure of about 75 psi was maintained, under normal circumstances, when all compressors were in operation. Compressors have International Harvester engines.

XUM

DESCRIPTION OF OPERATION

Robert L. Foree*

DRILLING an oil well today requires large investments in money and equipment, a thorough knowledge of the equipment and techniques of operation by specialists in many fields. Each well is a problem in itself, with special requirements in depth and geologic area, and peculiarities in formation structure, weather conditions, and completion aims. Purpose of this series is to acquaint the reader with various items of rotary equipment, the techniques and personnel employed, the variations involved and the associated services engaged by the rig owner to solve each drilling problem.

Preparation for Drilling

Although we are concerned primarily with only the drilling of a well, much work has preceded a rig's appearance on the well site. This work includes many very different operations. Deals have been made to obtain leases on land in possible oil and gas country by landmen. Seismic engineers may survey the area. Geologists study surface and subsurface stratigraphy as well as nearby or "offseting" wells, so that they can propose the depth and position. Specific location of the well is then spotted according to state regulations of spacing, lay of the land and populated areas. Legal procedures indicating intention to drill must be filed and requirements of state, and oft-times city, conservation boards must be met to prevent contamination of fresh water sands from drilling fluids.

Water, vital to the rotary operation, must be found (and paid for) from nearby lakes, tanks or wells, and in many cases the drilling of a water well is necessary.

After these things are done, the rig contractor chooses a rig suited to the depth and specific area. Often this involves addition of a steam boiler for heating in cold climates or special safety precautions in some localities.

Increase in offshore drilling has led to the development of a new type drilling rig, designed to operate for several days without outside help or supervision, other than that available by two-way radio communication. Although these rigs may employ different principles of suspension above the lake or ocean floor, most of them provide living quarters for all crew members, employ cooks and general helpers, maintain testing and logging equipment on the rig floor, and may even have helicopter landing decks.

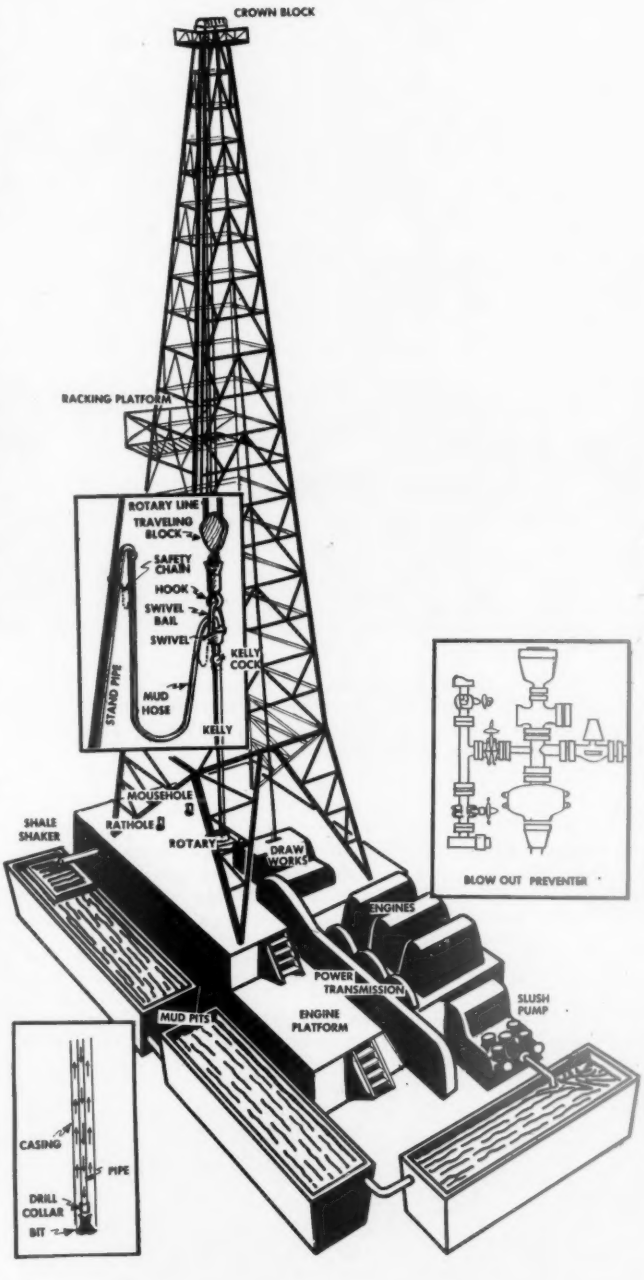
For land locations, bulldozers must prepare the drilling site, level the ground, make necessary access roads, and mud pits, if necessary, in the particular pattern desired by the contractor.

Moving In, Rigging Up

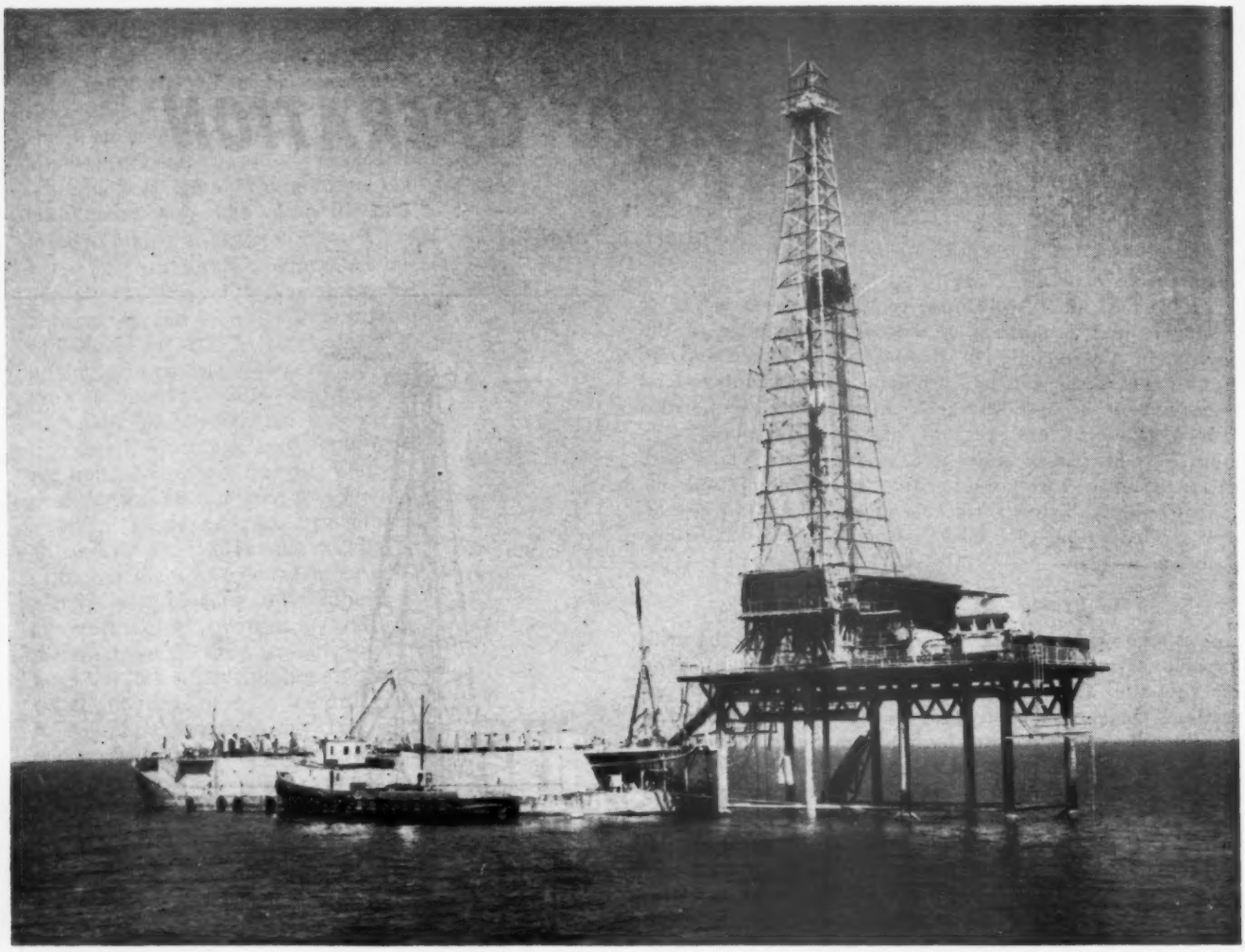
Moving in a rig has become a major phase of the drilling operation. Many rig owners invest large sums to increase the portability of their rigs and develop a high degree of efficiency and speed in moving in and erecting their equipment. More and more sections of the drilling rig are being made into compact, mobile units.

Derricks, drawworks, and engine units are now being wheel-mounted for moving to new locations with the slightest delay possible. These sections are fitted with kingpin and "fifth-wheel" connections for conventional truck tractor

*Independent Operator, Dallas, Texas.



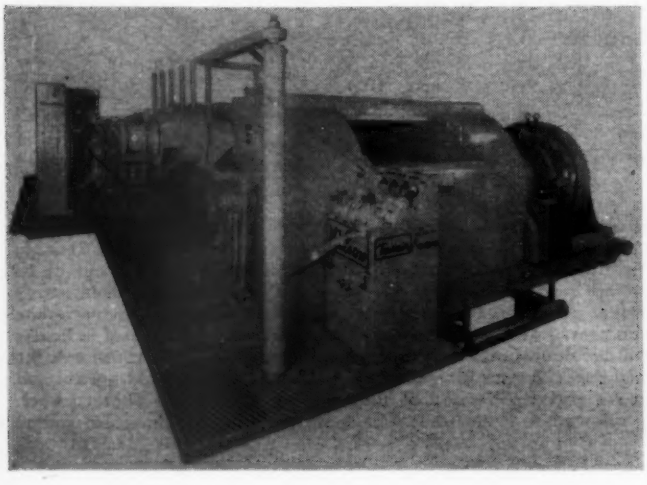
Drilling rigs vary in size and in capacity, although the component parts remain the same and in about the same position. This rig illustrates the principal parts. The blowout preventer, out of its normal position beneath the rotary table, is shown with its many valves and rams necessary for protection against excessive formation pressures and unexpected well flows. The lower inset indicates the circulating fluid coming from the slush pump down through the drill pipe, out the bit and back up the hole. This fluid is returned to the surface, cleaned of sand and cuttings in the shale shaker, is allowed to settle until it reenters the cycle at the slush pump.

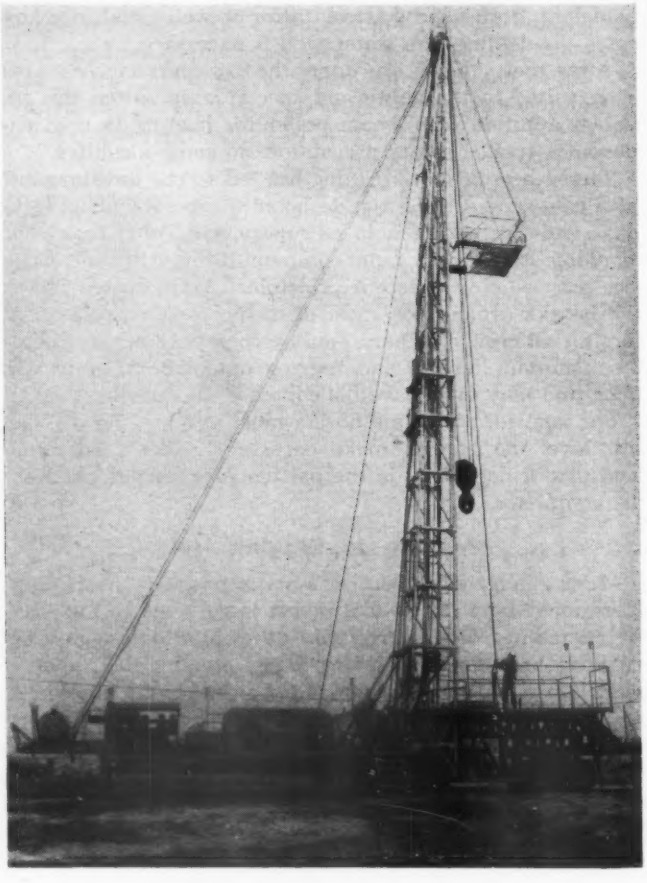


Although all drilling rigs must exist as independent units, offshore rigs such as this Parkersburg must operate for days without outside assistance. Complete living quarters are a necessary part of the rigs operating in the Gulf of Mexico.

The Franks Comet model trailer rig, at right, is in direct contrast to the large offshore rig. It is trimmed for speed and portability in moving and drilling. The Comet is applicable for drilling "slim hole" wells and well completion.

Below is the Wilson Super Titan "66" drawworks for the drilling of the deepest of deep wells. This rig has a power input of 2200 hp and depth rating of 22,000 ft.





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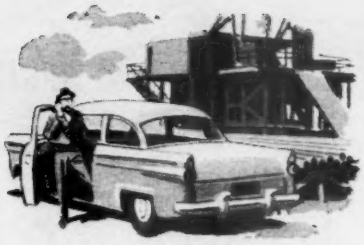

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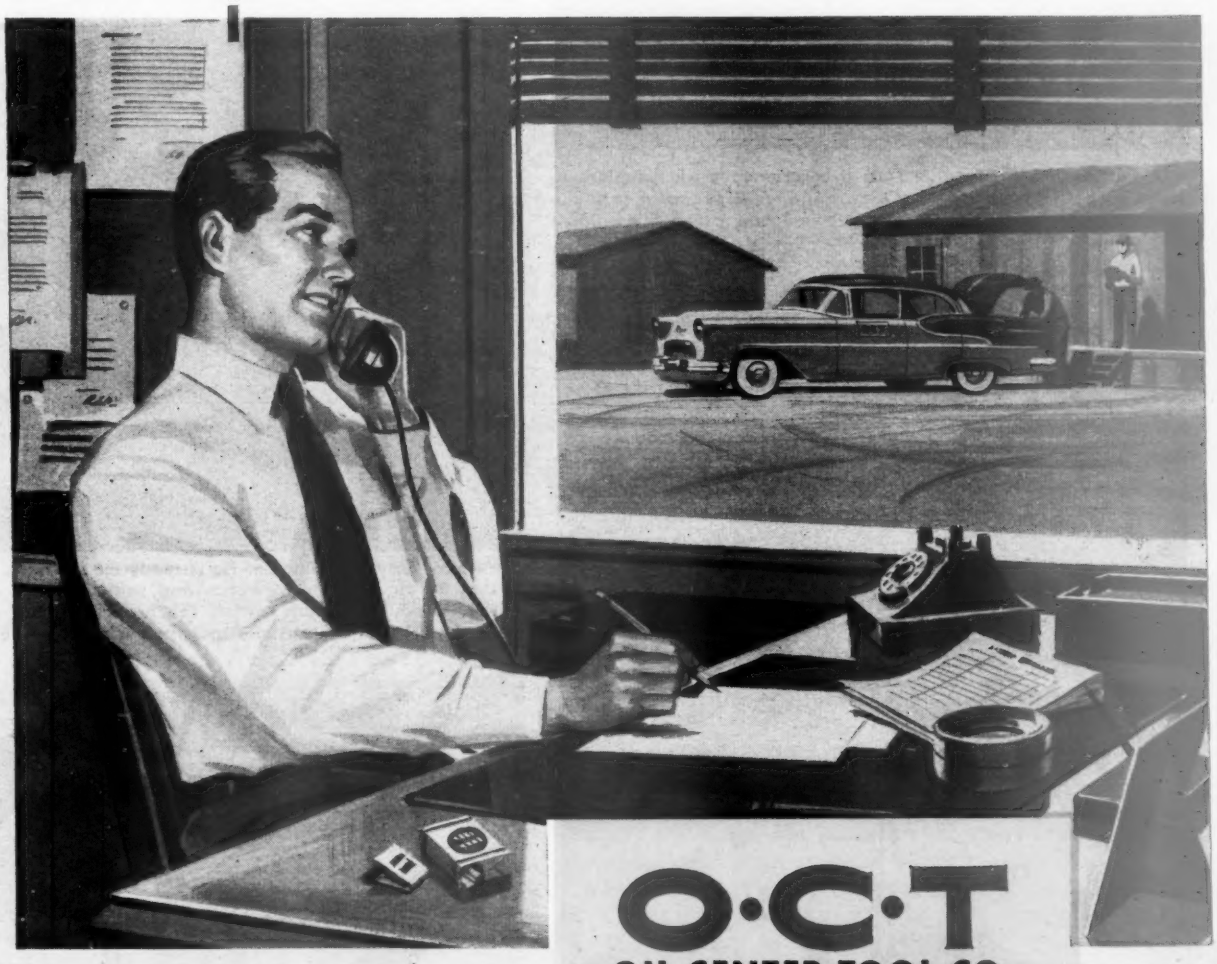

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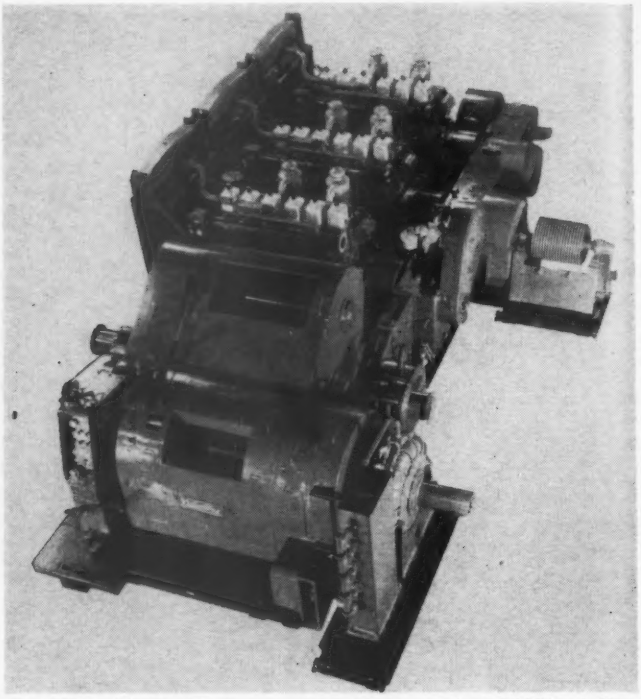
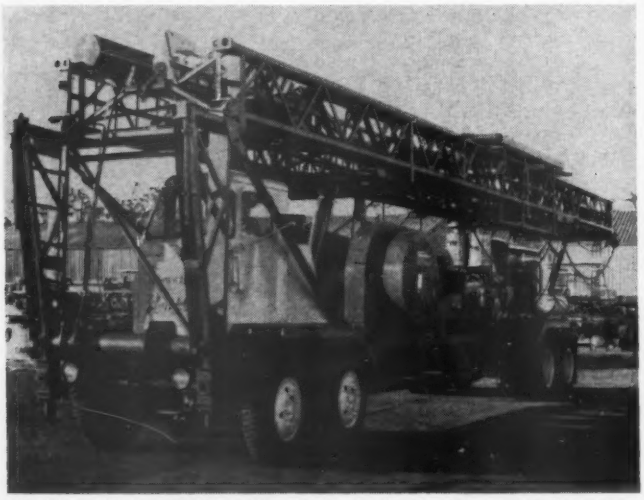
The Failing Holemaster "2500" is a completely truck mounted rig rated for 2500-ft drilling with 3½-in. drill pipe. Upper section of the mast is connected on location and hydraulically raised. Slush pump is also mounted on the truck.

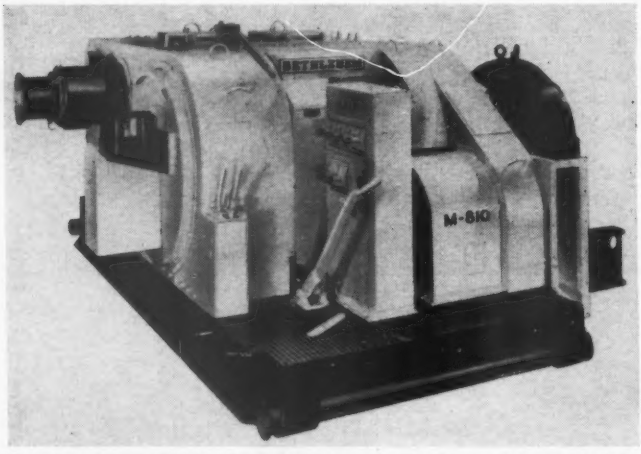


The "Oilwell" No. 76 drawworks is designed for 10,000-ft. drilling and has air-control panel at driller's position. Power from three engines is compounded to drive two slush pumps and the rotary.

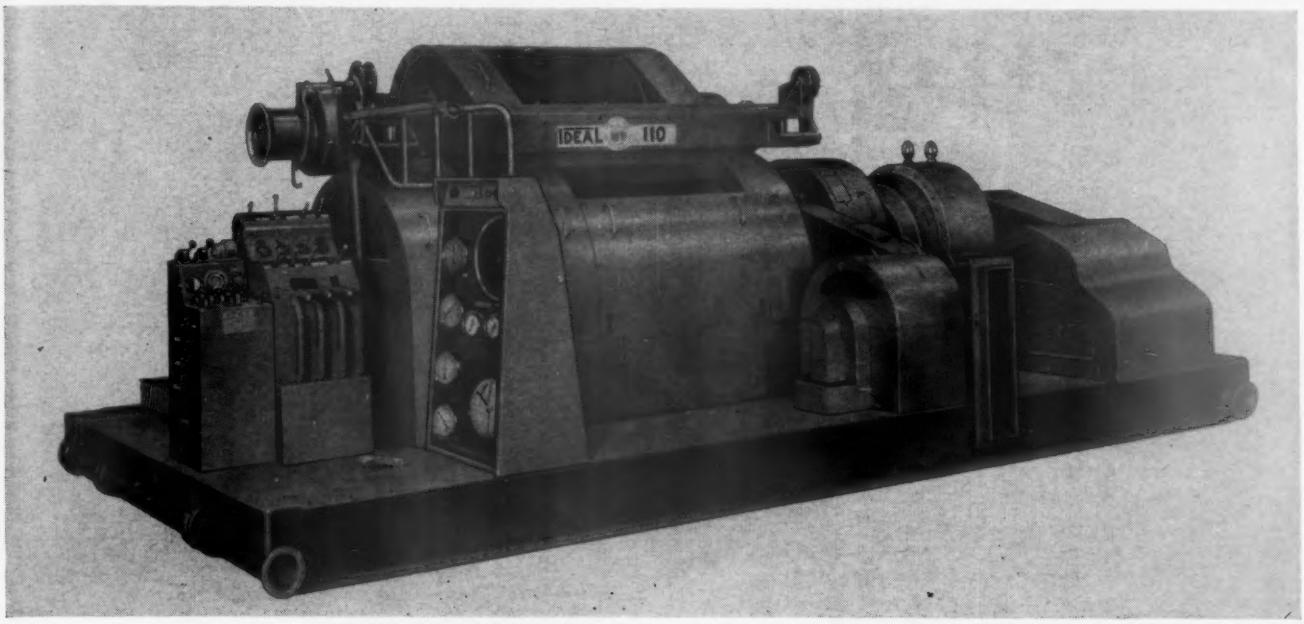


The Ideco "Drive-In" Rambler rig is ready for the road. It is unique in that the rig, mast, drawworks, and engine are all on a single self-propelled, road-width carrier. The drawworks has a maximum rated capacity of 350 hp, and mast can telescope to 95 ft.

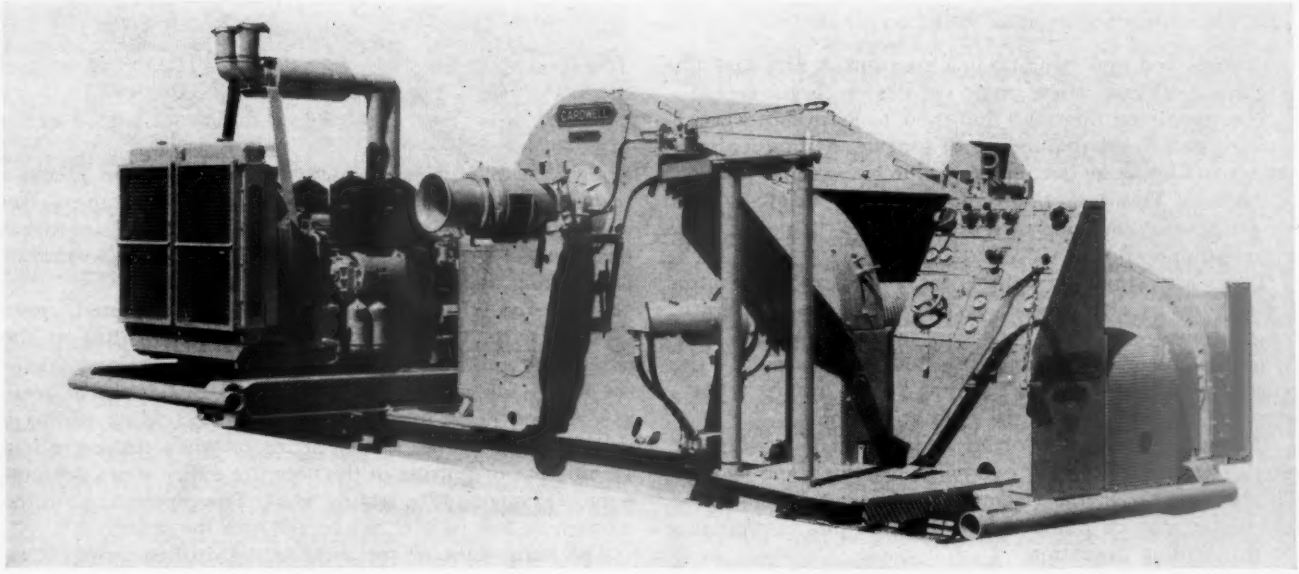
Deeper wells are now characterized by the API standard derrick. The drawworks of this one is an Emsco J-1100 on a location for a well probably to be projected past 10,000 ft.



This Bethlehem M-810 drawworks has a rated capacity of 1000 hp in the 8000-14,000-ft class. Modern rigs of this type compound drawworks and mud pumps together for increased efficiency and control.



National Ideal's Type 110 is best suited for drilling in the 9000 to 13,000-ft depth range. It is powered by either four engines in the 300-hp class or by three engines in the 400 to 500-hp range. Drawworks are assembled conforming to road width and load limitations.



Drawworks and engines of this Cardwell S-350 rig are skid-mounted separately for quick, easy loading and simplified rigging up operation. For drilling in the 3500-ft class, this rig has torque converter and air controls, luxuries on the larger rigs not long ago.

moving. Many shallow rigs are built on the bed of trucks for complete elimination of costly loading time. Rig "skidding" is common in established fields where short moves between locations are possible. The entire rig is slid along the ground with the aid of roller or sled-type skids pulled by teams of tractors.

The value of time at this stage of development cannot be underestimated. Standard derricks, for instance, which today are used primarily for drilling deeper wells, have given way to cantilever and telescoping-type derricks. These have eliminated piece by piece, time-consuming construction previously necessary to drill every well. The newer innovations make it possible for drilling crews to erect the entire rig ready for drilling in a matter of hours.

Trucks bring in drawworks and engines to be set into place on the rig floor. Slush pumps are placed by the mud pits; dog houses, fuel tanks, shale shaker, electric power plants and other equipment are set up in position. Drill pipe is delivered.

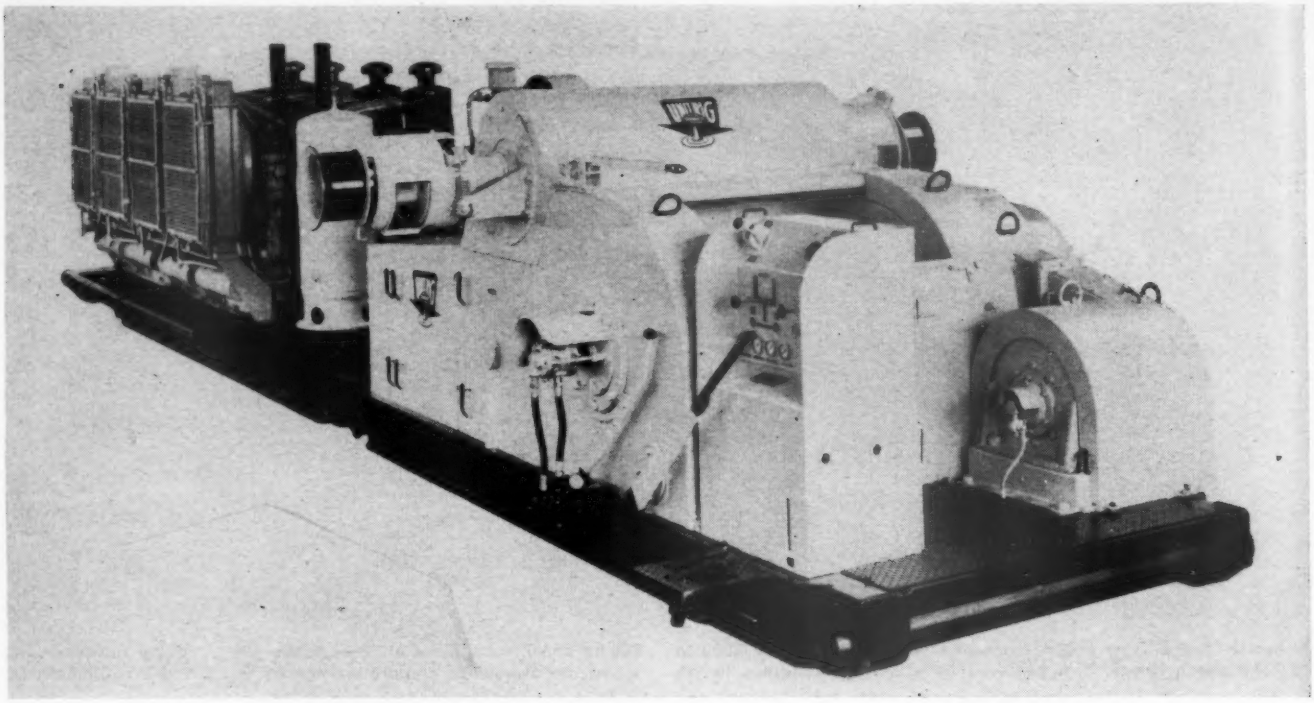
Drilling Personnel

Now the drilling crews go on tour to handle the rigging up. The average staff on duty at one time includes the driller, a derrick man, and two floormen.

There are three such crews all under the direct supervision of the *toolpusher*. He keeps in contact with the driller on tour, either by being on the job or through the media of two-way radio. As a rule, most toolpushers are drillers who have shown the ambition to asusme the responsibility of the 24-hour job.

The *driller*, a man possessing a high degree of muscular and mental coordination and competence from rig experience, has complete control of the drilling contractor's investment on his particular 8-hour period of duty.

The *derrick man* holds the next position. His title is derived from the work he does in latching and unlatching elevators and racking drill pipe from a position in the upper part of the derrick when the drill pipe is being run in or withdrawn from the hole. This man is usually in charge of



This Unit Rig U-40 is characteristic of the modern rigs in the medium depth class.

the pumps and mud conditioning program. A fifth man, the motorman, shares minor pump repairs on larger rigs.

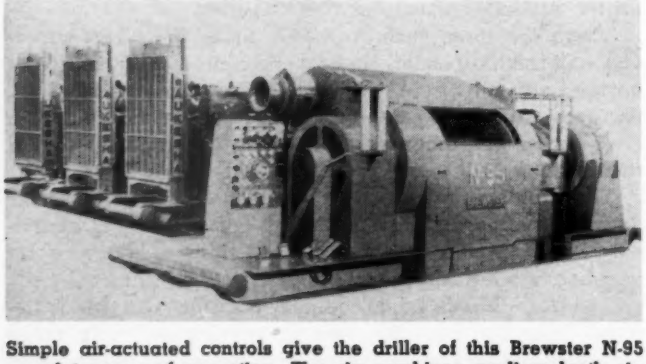
The remaining *floormen* find their tasks in motor maintenance and the manipulation of tongs and slips for making up and breaking out joints of pipe to be run in and out of the hole. This operation of going in and out of the hole, for purpose of changing bits, etc., is called "tripping." The complete operation is a "round trip."

Tongs are wrench-type tools for joining and separating the sections of drill pipe. Leverage for manually operated tongs comes from "jerk" lines from the drawworks. Air and hydraulically operated tongs are now being used for this operation. Slips—"wedges" seating in the rotary table—suspend the drill pipe in the hole at this time.

The entire crew is involved in many and varied tasks ranging from painting to overhauling pumps and motors. They must also, in the rigging up stage, lay water line so that water may be pumped into the mud pits in readiness for the drilling operation.

At this time, drilling line is fed into the traveling blocks and crown block, atop the derrick, and then rolled onto the drawworks drum. Engines are compounded with the pumps and drawworks; fuel, air, and electric lines put into position.

The heart of the rig is the drawworks, which acts as a hoist for lifting and lowering all equipment into the hole.



Simple air-actuated controls give the driller of this Brewster N-95 complete ease of operation. The rig combines medium-depth rig portability and power for economical drilling of deep wells in the 8000 to 14,000-ft class.

The drawworks line moves the hook and blocks—a giant block and tackle assembly for increasing the load capacity. This drill pipe and drill collar load may reach a dead weight of 200 tons.

Because the rig is in operation 24 hours every day, a complete electric power system must be maintained. Not only does this system provide light, but in most cases makes possible use of radio equipment, starting engines, recording and testing instruments, and air compressors.

When the initial rigging up has been completed, crews proceed with the first drilling operation—drilling of the mousehole and rathole, holes just ahead and to one side of the rotary table. In the rathole is kept the square of hexagon shaped kelly joint during the period when adding a joint of pipe to the drilling string or when making a trip (taking out or putting in the hole the entire string for purpose of changing bits, testing, etc.). The pipe is kept in the mousehole before it is "made up" into the string.

The kelly joint, or top joint of the drilling string, is revolved by the rotary table, usually turned by universal joint or chain drive from the central source of power.

Drilling Services

Drilling the main hole begins with a large bit for the purpose of setting the surface casing pipe. At this time the drilling contractor first calls on outside help. He requires a *cementer* to "anchor" the large casing string set at a depth sufficient to protect the annulus from intruding water and caving formation, and to protect water sands from the drilling fluid.

Secondly, the *mud engineer* is brought in to prescribe the particular mud program to be followed. The engineer will suggest additions to the drilling water in order to hasten drilling speed, to drill pressured formations safely and to protect the drillstem from caving structures. These additives take many forms: chemical, bentonite clay, barites, even cellophane and corn starch.

The contractor will also engage a *drilling bit man* to handle bit needs of the well. Pilot bits, reamers, and rock bits of several types must be obtained—each one chosen to drill maximum footage in a minimum time in a certain

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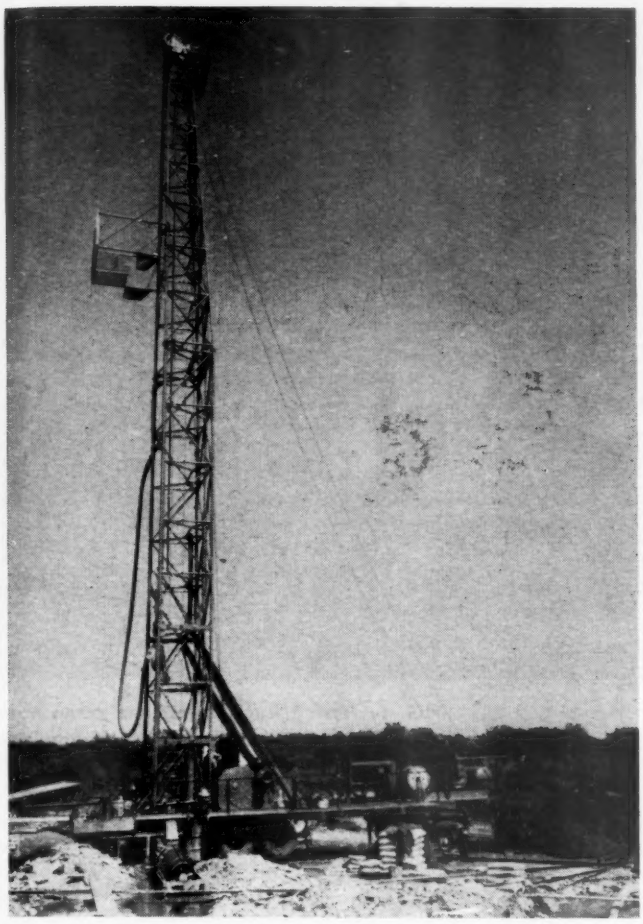


This Mayhew model 3000 portable rig is designed to drill to 4000 ft with 3½-in. drill pipe. Drawworks, engine and engine transmission, rotary table and the lower mast section are moved on one trailer. Mast is raised by two hydraulic lift cylinders.

formation or series of formations. According to local conditions and the dictates of the individual contractor, jet bits may be utilized. These make fullest use of the drilling fluid, which is forced down through the drill pipe and out through the bit, returning cuttings from the bottom of the hole. The jet bit is fitted with nozzles which spray the drilling mud, under pressure, out ahead of the bit to expedite its work.

The shale shaker cleans the drilling fluid of cuttings and other impurities picked up at the bottom of the hole by means of an agitating-straining process as the mud is returned to the mud pits. Sand and rock that have been cut by the bit are thus shaken and washed out of the fluid. After the fluid is returned to the mud pits, sufficient time is allowed for particles held in suspension to settle before mud is picked up again by the mud pump and sent back down into the hole.

Penetration Factors

The rate of penetration is dependent on several variables. These include the bit, weight on bit, rotating speed, and circulating fluid. Although the drilling contractor may only select the bit that fits his needs, he can directly control the other variables.

The weight-on-bit factor may be controlled by adding drill collars of extremely heavy steel pipe, between the bit and the regular drilling string. The drill collars are usually about 30 ft in length and vary from 6 in. to 8 in. in outside diameter. There may be as many as 20 collars at the bottom of the drilling string.

Drilling controls are available to regulate the feed off of drilling lines from the drawworks drum so as to maintain automatically a pre-selected, uniform weight on the drilling bit regardless of variations encountered in formations.

The rotating speed of the drilling bit depends upon the kind of formation, the type of bits, and depth of the hole—and in relation to torque limitations placed on the drilling stem.

Control of the circulating fluid lies in the volume and pressure of the mud down the hole, as determined by the length of stroke and diameter of the bore and speed of the slush pump.

Rig Power

The power for the pumps has been provided with the same mobility and compactness as are other rig components. Engines are now put together in "power packages" for direct compounding to the drawworks and mud pumps. Gasoline, LPG, and diesel oil are the most common fuels for these engines, although diesel-electric power is growing in popularity in certain areas. Steam as a prime mover has been used for many years and is common today on many large rigs on the Gulf Coast.

Power to operate the rotary table is usually drawn from a drive shaft on the drawworks. A separate engine, however, is sometimes used. Hydraulic power—similar to that used to agitate the shale shaker, engage brakes and other controls—is now being tried for this purpose.

Well Completion Practices

Cores are taken for a better study of earth structure than can be gained by cuttings analysis. To get a core involves replacing the conventional bit with a core barrel and special bit that retains a cylindrical, unbroken, uncontaminated section of the formation being drilled. The core barrel resembles a drill collar in appearance and size with a multicutter or diamond-tipped bit.

While the rig is still on location, the well is usually electric logged and the "pay" zones are drillstem tested. Both these services are performed by engineers. Electric logging records formations as encountered in the well bore, showing on film a different reading for each texture. Drillstem testing samples the potential strength of the porous horizon, whether oil, gas or salt water.

On completion of a successful well, casing pipe is set by the drilling crew. This pipe, which is cemented into place, prevents fluid intrusion or formation caving in the pay zone. To open the producing formation into the pipe, this section is perforated with holes by means of bullets or shots detonated from explosive-charged chambers. This service is performed by perforating specialists.

Substitution of air and natural gas for the conventional fluid circulating media may prove a new horizon in the drilling field. Air compressors would replace the slush pumps in this case. Standard rotary equipment is used in this method, eliminating the need for mud pits and shale shakers.

Such changes in drilling reflect the constant change undergone on each rig and the industry as a whole. Although the aim today is the same: Drilling wells fast and at low cost, the emphasis has changed concerning the method of arriving at this end. Not so long ago, the drilling of a well was associated with wooden derricks, jack-posts, and large drill pipe, and was surrounded by a waste in materials, in oil and in manpower.

No longer does the drilling contractor think in terms of "doing it bigger," but rather in "doing it better" with relation to weight, time, safety and profit considerations—a more-power-per-pound approach.

With this set of values in mind, the rig of today takes on a complex appearance. Each individual rig is a composite of many separate pieces of equipment, interlocked into a singular tool to drill satisfactorily a hole in a particular depth range and a particular geologic area.

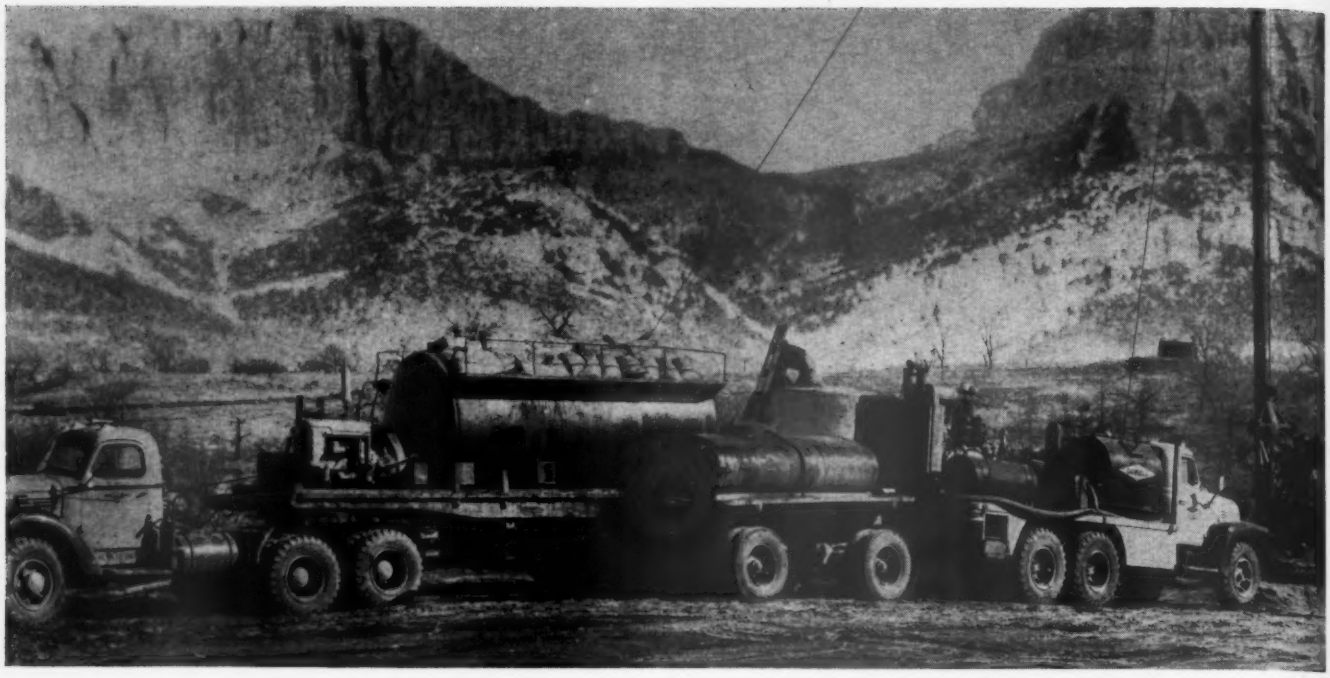


FIG. 1. Mixing truck at left and pump truck at right prepare to fracture Rocky Mountain well.

Tailor-Made FRACTURING Pays off in the Rockies

Best results indicated by prescribing treatments based on individual well study and conditions

Warren L. Sallee and Al Gionta

EXCLUSIVE

IN order for fracturing to provide maximum stimulation of wells in the Rocky Mountain area, various types of fracturing fluids are employed. For each well, a specific fracturing fluid is selected, together with auxiliary chemicals, sand concentration, and treatment technique. These selections are based on field experience, data and research that provide a practical knowledge of the producing formations and the manner in which it responds to fracturing treatment. Results have indicated that such fracturing treatments designed for each well are providing substantial production increases in the Rocky Mountain area.

Although opinions differ as to the manner in which these production boosts are achieved, theoretically, hydraulic pressure is utilized to induce fractures in the formation, by means of which formation fluids can reach the well bore. Sand carried into the formation by the fracturing fluid remains, holding open the fracture after the hydraulic pressure has been released.

Fracturing Fluids

Not only should a fracturing fluid be readily available and economical, but it must suspend sand adequately and have proper fluid loss characteristics. In the well, it must thin at the proper time and not form a stable emulsion that might limit production. Further, it should not discolor stock tank oil.

Fracturing fluids can be classified as:

(1) Hydrocarbon gels
(2) Aqueous gels
(3) Emulsions

(4) Refined oil
(5) Lease oil
(6) Miscellaneous fluids.

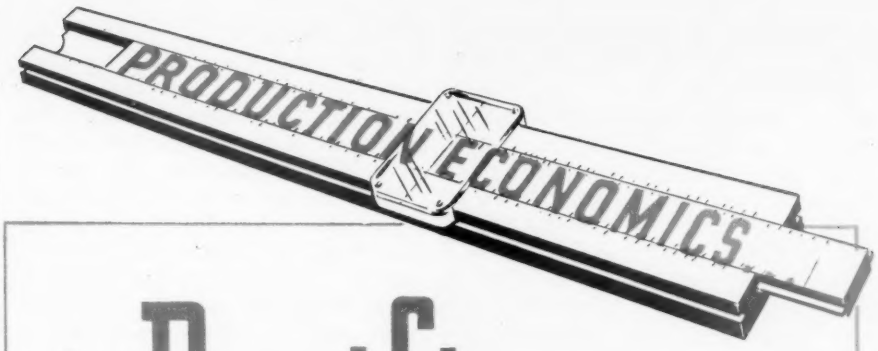
Hydrocarbon gels are prepared by adding gelling agent to the hydrocarbon, increasing its viscosity so that it will support sand adequately. In the formation, the gel is broken by the presence of salt water or a mineral acid, or by dilution with additional quantities of hydrocarbon fluid. A gel breaker also may be employed.

Aqueous or water-base gels, such as thickened hydrochloric acid, are similar in many respects to the hydrocarbon gels. They are formed by the addition of a gelling agent or thickening agent to brine or acid. An added advantage in the use of the acid type gel is the combined fracturing and acidizing action that is obtained in treating a calcareous formation. This reaction with the formation results in the "breakdown" or thinning out of the viscous fluid, allowing it to be returned to the well bore following the treatment, without the use of an auxiliary gel-breaker.

Gel acids are adaptable to a wider variety of well conditions than are hydrocarbon gels because the composition may be varied as the solubility of the formation varies. The viscosity of the gel may be controlled over a wide range, as the treatment dictates. However, fracturing fluid having a high viscosity requires increased surface pressures for pumping as a result of friction losses.

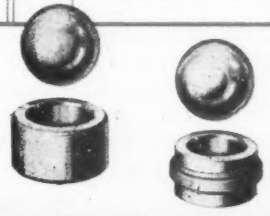
In acid soluble formations, gel acids cause the deposition of a temporary film that reduces fluid loss without requiring a high viscosity. Inert solids may also be added to these solutions to control the fluid loss.

Another type of fluid carrying agent is the controlled emulsion composed of acid and some hydrocarbon, usually kerosine. These emulsions are sufficiently viscous to carry sand in suspension and act as fracturing agents in a well. They also possess exceptional sand carrying ability, due to the thixotropic nature of the emulsion. However, they are basically unstable and are designed to revert to a free-flowing fluid within a few hours following the treatment. This breakdown is brought about either by the presence of an acid reaction product, or due to the emulsifying agent being adsorbed onto the surface of the formation. The chief advantage of this type of fluid is its ability to revert from a high viscosity to a low viscosity without the aid of an auxiliary gel breaker. This property is advantageous in extremely low bottom hole pressure wells where lengthy clean-up periods may be required after other type fracturing treatments.



by Pacific PUMPS INC.

	QUESTION		ANSWER
Q	*Why is oil at the bottom of the well like money in a safe deposit box?*	A	Because it is a LIQUID ASSET IN DEAD STORAGE WITHOUT EARNING POWER.
Q	*Can this condition be changed?*	A	Yes — both can be activated and given earning power.
Q	*How can they be activated?*	A	Draw some of the money from the safe deposit box — purchase and install a Pacific Oil Well Plunger Pump in the well — pump the oil to the surface. MONEY IN CIRCULATION — OIL IN CIRCULATION — BOTH WITH POWER TO EARN.
Q	*Why purchase and install Pacific Oil Well Plunger Pumps?*	A	Because only Pacific gives you the EXCLUSIVE MOLOY® LINERS with the strength, toughness, hardness, combined with greater resistance to temperature, corrosion and abrasion essential for long, economical life.



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Valves and Seats — To fit well conditions.
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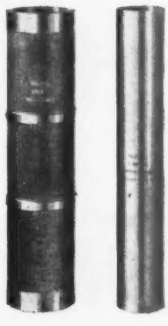

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The fluid loss of an emulsion is usually quite high. When a low fluid loss emulsion is desired, the acid phase may be made from gelled acid, or inert solid particles can be included.

In many cases, special refined oils are used as a fracturing fluid. These consist of crude oil from which the very light and very heavy hydrocarbons have been removed. Fuel oils, rather than kerosine, are most commonly used. By blending these heavier fuel oils with kerosine, practically any desired viscosity may be obtained.

The advantage of using a refined oil fracturing fluid is that, in the formation, it absorbs large volumes of free gas. This causes thinning and allows it to return to the well bore as a free-flowing fluid that does not discolor or seriously lower the gravity of the stock tank oil. When used in areas where emulsion problems have previously been encountered, a conditioning agent is usually incorporated in the fracturing fluid to prevent stable emulsions from forming, and to facilitate the return of the fracturing fluid.

Although lease oil has been used occasionally to perform fracturing treatments, it is less desirable than refined oil for a number of reasons. For one thing, such crude oil usually contains a number of fine particles that may be instrumental in causing emulsion difficulties in the formation. The sand carrying ability and fluid loss properties of most crude oils are very poor. Higher injection rates are required to obtain the same fracture penetration accomplished by more viscous fluids. Low concentration of sand must be used or screenouts are likely to occur. In addition, a definite fire hazard exists when crude oils are handled in open tanks around pumping equipment.

Graded sand injected into the fractures during the treatment, acts as a propping agent to hold open the fractures. The permeability of the injected sand bed will be much greater than the original formation permeability. Most of the sand used in fracturing work to date has been graded sand of a distinct size range, such as 20-40 mesh, or 40-60 mesh. Such sand, because all particles are more nearly the same size, will show greater "in place" permeability than will a sand having a greater range in particle size. In an ungraded sand, the small sand particles tend to fill in the voids between the larger sand particles.

Most fracturing operations are conducted using round-shaped sand grains. For some applications, however, angular-shaped sand may be preferable, because of its scouring action even though higher pressures are required to inject it into the formation. Generally speaking, the angular sands appear to give better results in softer, incompetent formations.

A recent improvement in fracturing techniques has been to use two or more kinds of sand. For example, in a tight section of formation a small size round grain sand might be used initially, followed by a coarser round grain sand.* This coarser sand could penetrate readily the opening in the formation already formed by the finer sand preceding it. This would result in maximum advantages, in regards to extent of fracture, residual permeability and decline curve.

The proper concentration of sand, carried in the fracturing fluid, is determined by the type of carrying agent, the nature of the formation being treated, and the equipment through which is must be pumped. Results improve, in general, as the size of treatment is increased.

Other chemicals frequently are used to increase the effectiveness of a fracturing treatment. Mud acid may be employed to disintegrate the mud cake from the face of the formation. This results in lowering injection pressures, and dissolving materials that may cause restriction to flow. Special additives may be included to reduce silicate swelling, prevent emulsions, and decrease surface tension.

It is often advantageous during the fracturing treatment, to divert the fracturing fluid from existent fractures in order that additional fractures may be opened. This may be accomplished by injecting a thickened kerosine-base fluid carrier, containing graded solid particles that filter out, forming a filter cake to seal off the fracture. These solids react with each other in the filter cake, resulting in their subsequent liquefication. Thus, the filter cake is designed to destroy itself, leaving nothing behind to interfere with production from the previously plugged zone.

Case Histories

The application of these fracturing techniques to the various formations in the Rocky Mountain Area, has resulted in gratifying production increases, in both old and new wells. Representative examples are listed in Table 1, together with production data.

That the fracturing treatment produces a satisfactory production increase is, of course, important to the operator. Of equal importance is the rate of decline of the stimulated well. Increased production should be sustained if the fracturing treatment is to be considered a success. Fig. 1 is a typical decline curve of a well producing from the Frontier Sand in Wyoming. After fracturing, the additional production had paid for the treatment in slightly over a month. During a subsequent period

*U. S. patent 2354570.

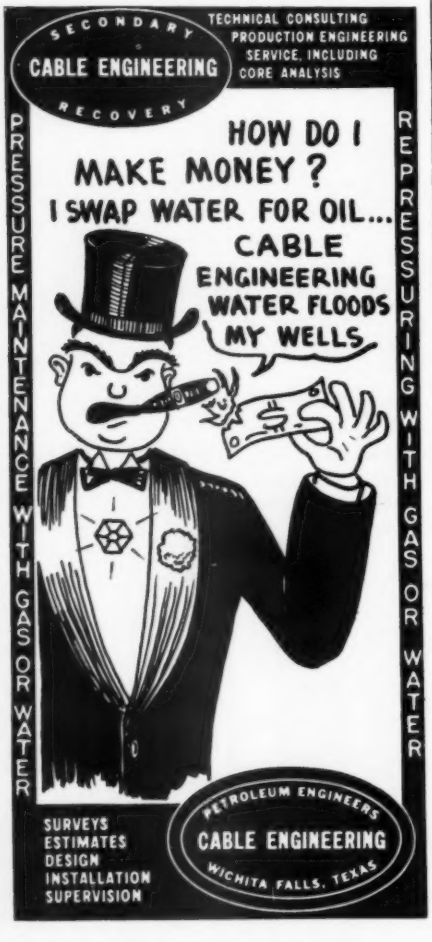

TABLE 1. Fracturing results (Wyoming).

Formation	Previous Treatment	Fracturing Flu (gal)	Sand (lbs)	Prod. Before	Prod. after
Embar lime (new well)	12,000 acid	6000 with 8000 acid 250 Temp plug— 2 zones	12,000	Swabbed Dry	225 Bopd (Swab) 165 Bopd pump tst
Embar lime (old well)	5000 acid (comp) (40 Bopd)	3000 with 4000 acid	7500	12 Bopd	63 Bopd
Tensleep (old well)'	None	1500 with 1500 mud acid 1500 mud acid	2250	4 BO/ /45 BW	29 BO/ /135 BW
Tensleep (old well)	None	250 temp. plug 2500 temp plug	2500	62 Bopd	190 Bopd
Embar lime (old well)	5000 acid	3000 with 5000 acid	6000	15 Bopd	60 Bopd
Shannon Sand (new well)	None	3000	3000	15 Bopd (Swab)	132 Bopd (pump)
Frontier (old well)	Fractured (no improvment)	4000	4000	19 Bopd	75 bopd

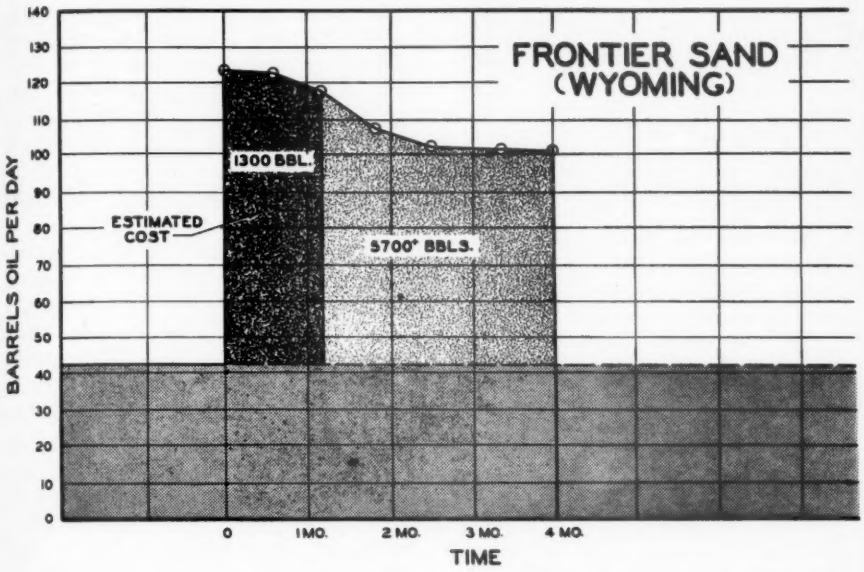

FIG. 2. Decline curve of a new well producing from the Frontier sand in Wyoming.

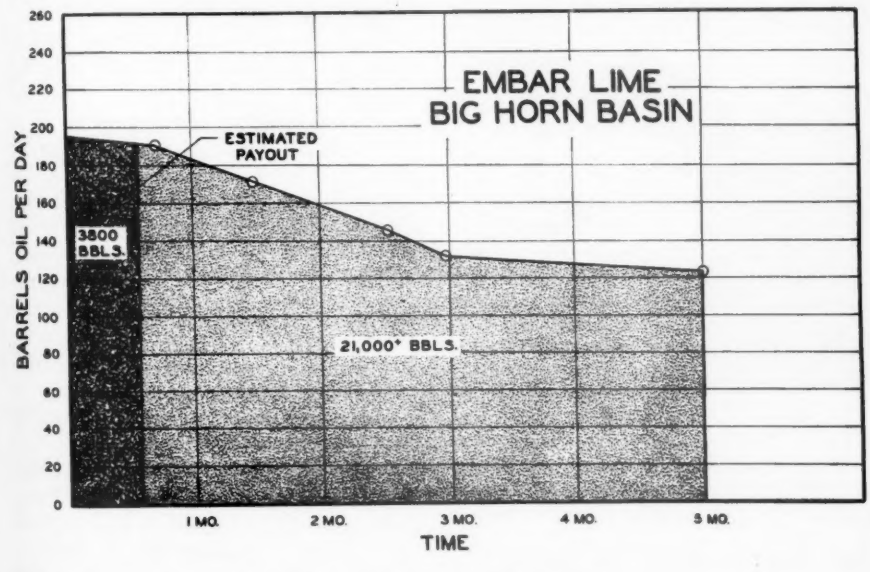

FIG. 3. Decline curve of a new well in the Big Horn Basin.

of less than 3 months, 5700 bbl additional were produced. Fig. 2 is a typical decline curve of a new well in the Big Horn Basin, producing from the Embar Lime. The 3800 bbl of oil required to pay out the treatment was produced in little over 2 weeks. During the subsequent 4½ month period, 21,000 bbl of oil were produced.

Although generalizations are difficult, it appears conclusive that the fracturing process is providing profitable results in most instances. In addition, fracturing is certainly stimulating new field of activity in the Rocky Mountain area that should result in the addition of significant volumes of oil to the nation's recoverable reserve. * * *

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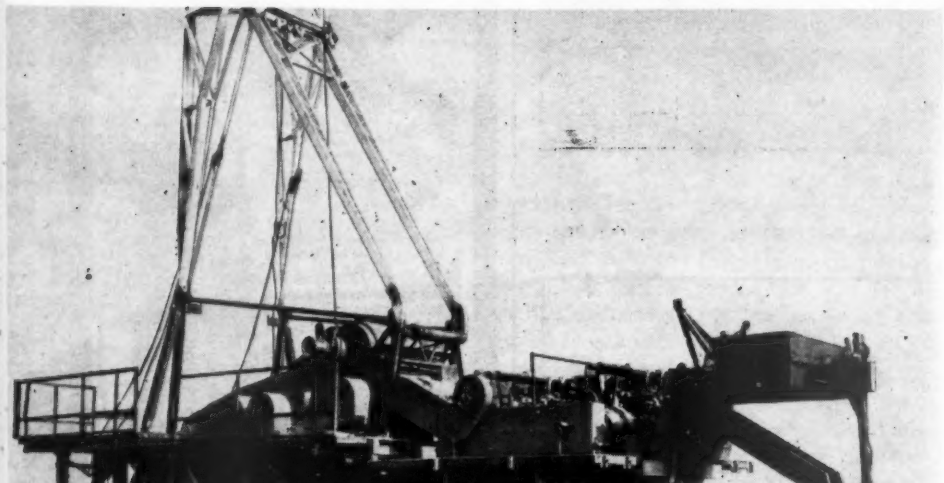
To obtain more information on products advertised see Page E-43

Trailer-Mounted Rigs Cut Downtime Between Wells

This trailer-mounted rig, for use in foreign operations, is one of the largest ever made. It has a sand reel, dual engine drive, and extra fuel tank over the trailer "gooseneck."



Drawworks, engine, and masts take to the road in a renewed effort to diminish valuable moving and rig-up time

Neil B. Biggerstaff

UNTIL a few years ago, trailer-mounting was considered applicable to only the smallest rigs, essentially those used for well-servicing. Now rigs capable of drilling to 4000 ft and deeper with 4½-in. drill pipe are being trailer-mounted for use in the United States and even larger rigs are being trailer-mounted for service in foreign operations.

It is interesting to conjecture as to what depths will be reached by the trailer rigs of a few years from now. The answer will be different for the United States, with strict highway limits enforced in most states, than it will be for foreign operations, where there are usually no such limitations to consider. It is safe to say, however, that both in the United States and abroad, the trailer rigs of the future will be able to drill efficiently to greater depths than those of today.

For operations requiring sizable moves between holes, the mobility of a trailer rig is a great advantage. Recently a drilling contractor in Texas reported that he was able to tear down, move, and be rigged up in 16 hours at a new location 70 miles away. At about the same time, a contractor in Wyoming, using a rig of the same type, but with the drawworks, power equipment, and mast mounted on a 10-ft substructure, reported that moves ranging from one-half to five miles each required an average of 15 hours.

Less Time Lost Between Holes

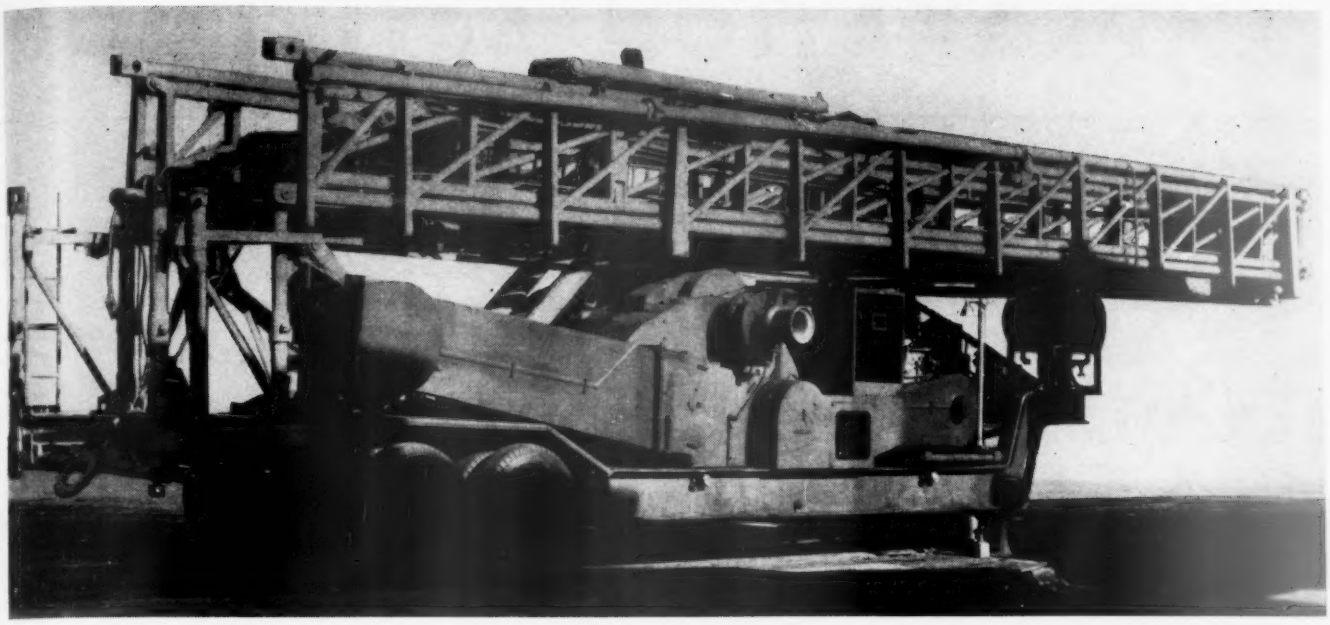
With a trailer rig, when the hole is finished, the mast is lowered and retracted, a truck is attached to the trailer, and the rig is transported to its next location. A second truck hauls the substructure while a third moves the pumps. It is not necessary to disturb the alignment of the engines, the drive to the drawworks, and the rotary drive. Blocks are left permanently strung, the mast does not have to be dismantled, and the rig floor set-up is permanent.

Not only is moving time between holes reduced, but also the damage to equipment, caused by frequent assembly and disassembly, is lessened.

Although the use of a trailer-mounted rig keeps quite a bit of "rolling stock" tied up and idle much of the time, many operators believe the rig's greater mobility compensates for this.

The popularity of "slim hole" exploratory drilling has added to the interest in the trailer-mounted rigs. By drilling small holes, using 2⅞-in. or smaller tubing, a rig can reach far greater depths than would be advisable using 4½-in. pipe in normal drilling. For instance, one rig*, normally considered appropriate for drilling in the 1500 to 3000 ft ranges, is being used

*National T12.



This trailer rig carries a draw works big enough to drill to 7500 feet with 4½-inch drill pipe, as well as the engines and a 96-foot mast. The axle load exceeds that permitted on United States highways. Jacks take the weight off the trailer bogie during drilling operations. The mast requires the use of two guys.

successfully to drill slim holes to 4200-4300 ft, and can drill considerably beyond that depth. Because this rig is trailer-mounted, it can be moved from a location in central Oklahoma to a new location in Kansas, 460 miles away, in 20 hours.

Use Folding Telescoping Masts

Contributing toward the trailer-mounting of more powerful rigs has been the development of new telescoping and folding structural masts that are lighter and easier to transport than earlier derricks. A mast that is nearly 100 ft tall when extended, can be retracted to about half that length and folded down on a trailer. The trailer also carries the drawworks, rotary, engines, and drive, without exceeding the customary state highway limitations.

Some of the newest masts are guyless, lessening the time and trouble of rigging up. The trailer rolls up a ramp and is locked into position on a substructure that provides the necessary rigidity and stability.

In most states, if a vehicle travels the public highways its width with its load cannot exceed 8 ft and height cannot exceed 12½ ft. Most rigs offered today, whether trailer-mounted or not, are kept within these limitations, or are made in sections, each of which is within the limitations.

When a rig is mounted on a trailer, the matter of weight becomes very important. An oversize sand reel, for instance, may put a rig above the weight limit. Dual or triple trailer arrangements are being used in some cases to transport rigs that are too heavy for a single trailer.

Weight Carefully Distributed

One dual trailer rig carries the drawworks, engines, and mast support frame on one trailer, with the total weight distributed to place 17,710 lb on each rear axle. The other trailer carries the mast, rotary substructure, rotary, and hookblock, with 16,750 lb on each rear axle. This keeps the load within the limit of 18,000 lb per axle that is enforced in a number of states.

A mast manufacturer is offering a three trailer arrangement for a rig rated for drilling to 5000 ft and deeper with 4½-in. drill pipe. The drawworks, together with its engines and drive, is mounted on a triple axle trailer. The mast is hauled on two additional trailers.

When it is planned to use a rig much of the time in a small area, rarely going on paved roads, state highway limitations are less significant. Whenever the highways are used, part of the load can be removed from the trailer. If a rig travels considerably from field to field, however, and is so big that heavy equipment must be removed in order to use the highways, part of the advantage of trailer-mounting is lost.

Fewer Limitations Overseas

For foreign operations, there are usually no highway limitations to consider, so the weight of a trailer rig is less important than its mobility over rough roads and rugged terrain. Several trailer rigs used in Venezuela have drilled without difficulty to 7500 ft. These use guyed masts, and employ jacks to take the weight off the trailer bogie during drilling operations.

Guyless rigs, with ramp-type substructures are now coming into use in foreign operations. The lack of a weight limit permits more engine horsepower and additional accessories to be mounted on the trailer. One rig has a sand reel, dual engine drive, and an extra fuel tank over the trailer "gooseneck."

Trailer-mounting of the larger rigs has been handicapped by the difficulty of utilizing the drawworks engines to drive the pumps. To overcome this, operators in foreign areas are considering the use of a countershaft from the engine drive to drive a propeller shaft that is direct-connected to the pump. Another solution is to trailer-mount the pumps.

The lack of highway limitations in foreign operations make it seem that a rig of any size, even the largest, might be trailer-mounted. If a trailer load becomes too big or to heavy, however, the vehicle's mobility over rough roads and rugged terrain is reduced, and the advantages of trailer-mounting are lost. Similarly, if the load is distributed among a whole procession of trailers, in order to get mobility, the amount of capital tied up in rolling stock may become excessive.

The answer for the future, both at home and abroad, probably lies less in packing heavier rigs on trailers than in putting more power into a trailer rig of a given size and weight. Manufacturers are doing much to reduce the size and weight of components. It can be expected that the increasing use of trailer-mounted rigs will accelerate this trend. * * *

XUM

EXPLORATION ACTIVITIES

KANSAS

★ Gulf has completed its No. 1 Zora as a direct offset to the discovery well in Pyle field, Kiowa County, for a maximum 24-hour potential of 3000 bbl calculated. Located 12 miles from Greensburg, the well drew the top permissible state rating on bottomhole gage test which showed an indicated productivity of 5093 bbl daily. Production of 36.7 deg oil through perforations came at 4640-50 ft in the Mississippian, topped at 4637 ft, after reaching a total depth of 4699 ft. The opener, No. 1 Clara Pyle, of Gulf and Falcon-Seaboard Drilling was completed last January for a state potential of 304 bbl.

MICHIGAN

★ Pure Oil Company has finaled a discovery about 14 miles from the Detroit city limits. The initial producer in the area from the Niagran limestone, flowed 174 bbl of oil in 4¼ hours on test from a section at 3091-3102 ft. The well is officially designated as the Pure-Taggart Crowe-Fraser Consolidated No. 1. There are other wells in the area that produce from the Trenton.

TEXAS

★ Phillips Petroleum Company has a third discovery well on its 22,000 acre block in northeast Gray County in the Texas Panhandle. The new well, the No. 2 Delp, without acidization flowed gas through 1-in. top and ⅝-in. bottom chokes on successive drill stem tests at daily rates of 12,600,000 and 13,200,000 cu ft and a spray of condensate from 20 ft of Granite Wash in intervals 7732-7742 ft and 7742-7752 ft. Coring and testing of the well are continuing. The new well is five-eighths of a mile northwest of Phillips No. 1 Delp, an oil discovery completed last August in a different pay section of the Granite Wash at approximately 9500 ft, and 1½ miles from the company's recent Ellenburger oil discovery, the No. 1 Troy "A" The No. 2 Delp is 15 miles northeast of Pampa.

★ Discovery well in the new Black Hill field, located in Maverick County some 20 miles east of Eagle Pass, is Continental Oil Company's N. J. Chittim No. 1 well. The wildcat was completed at a total depth of 4134 ft in fractured Eagle Ford shale. On open hole test it flowed 103 bbl of 28.6 deg oil and 26 Mcf of gas through a 6/64-in. choke in 24 hours. Tubing pressure was 825 lb and gas-oil ratio was 252 to 1. Five-and-one-half-inch casing has been set to 3109 ft. Conoco controls approximately 145,000 acres in the immediate vicinty. Nearest previous production is in the Chittim Field, about five miles north, where production is from the Rodessa limestone at 6000-7000 ft.

★ Discovery allowable has been requested for a Runnels County dual oil discovery of W. W. West. The No. 1 Lillie B. Fennell flowed from both the King sand and Cisco reef, on a location 4½ miles west of Winters. Flow from the King sand gaged 199 bbl of 43.8 deg oil with no water, and had a gas-oil ratio of 489-1. The upper sand was picked up at 2763 ft and tested through perforations at 2764-2774 ft on a 16/64-in. choke. This section was washed with 500 gal of mud acid. The lower pay, the Cisco reef, yielded 224 bbl of 43.8 deg oil, with no water, on initial test. The Cisco was topped at 2816 ft and test was conducted through perforations at 2929-2949 ft on same size choke. This completion was natural. Tubing pressure was 210 lb, with packer on casing.

CALIFORNIA

★ M J M & M Oil Company has moved in to drill a wildcat in the dry hole country of San Luis Obispo County, 3 miles southeast of Paso Robles. The well will be located on Sec. 11,27s-12e and will be designated Stanford-Johnston No. 1. It is expected to explore for Vagueros sand production between 3500 and 4000 ft.

★ Sunray Mid-Continent has recompleted Fred Smith A No. 76-34 for initial production of 550 bbl daily 36 deg crude. SDX went back into the suspended well and made the discovery in the Basil Temblor sand while testing up the hole. The well is located on Sec. 34, 20-16 in the Guijarral Hills field of Fresno County. Production is from an interval between 7885-7908 ft. SDX has now moved to an old producer, Allison A No. 52-34, one-half mile northwest of the Fred Jones well to conduct a similar test.

★ Union Oil Company and others will drill a new wildcat one mile north of nearest production in the Guijarral Hills field of Fresno County. The test is to be known as Helm Company, Hans R. Sumpf and Robert Sumpf, Pleasant Valley No. 8-14 and will be located on Sec. 14, 20-16.

Summary of Drilling Activity for April.
(As compiled by Rinehart Oil News Staff)

States	New locations		Wildcat completions			Field completions			Junked & abnd.		Temp. abandoned		Abandoned locations		Current active wells	
	Wc	Field	Oil	Gas	Dry	Oil	Gas	Dry	Wc	Field	Wc	Field	Wc	Field	Wc	Field
Alabama	7	15	0	0	11	7	0	7	1	0	0	0	0	1	3	1
Arizona	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Arkansas	12	56	0	0	7	34	0	19	0	1	0	1	0	1	10	24
Canada (Williston B.)	15	51	0	0	9	42	0	2	0	0	0	0	0	7	8	13
Colorado	59	58	3	2	55	22	3	16	1	0	0	0	0	0	50	59
Florida	6	0	0	0	1	0	0	0	0	0	0	0	0	0	4	0
Georgia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Idaho	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Kansas	92	266	10	3	64	150	32	90	0	0	0	0	0	0	68	395
Louisiana	62	289	4	5	26	162	23	49	0	3	4	6	2	16	88	272
North	17	147	0	0	8	97	6	17	0	0	0	5	1	11	13	56
South	33	121	2	4	15	55	17	31	0	1	4	1	0	5	55	181
Offshore	12	21	2	1	3	10	0	1	0	2	0	0	1	0	20	35
Mississippi	19	41	0	0	12	15	1	15	0	0	0	0	0	1	17	19
Montana	7	17	0	0	3	5	0	3	0	0	0	0	0	1	17	21
East	3	7	0	0	1	2	0	0	0	0	0	0	0	1	7	10
West	4	10	0	0	2	3	0	3	0	0	0	0	0	0	10	11
North Dakota	4	12	0	0	5	13	0	3	0	0	0	0	0	0	3	21
Nebraska	15	32	5	0	9	18	2	12	0	0	0	0	0	0	20	48
Nevada	0	3	0	0	0	3	0	0	0	0	0	0	0	0	1	1
New Mexico	27	143	0	0	12	87	29	5	0	0	0	0	0	1	40	189
Eastern	10	93	0	0	10	86	4	4	0	0	0	0	0	1	28	125
San Juan	17	50	0	0	2	1	25	1	0	0	0	0	0	0	12	64
Oklahoma	58	565	4	1	45	387	19	126	0	0	1	8	3	37	64	511
South Dakota	1	2	0	0	4	2	0	2	0	0	0	0	0	0	1	0
Texas	548	1525	81	8	275	836	50	163	4	0	3	13	3	36	431	903
East	31	71	1	0	19	15	10	8	0	0	0	1	1	0	19	73
Gulf Coast	39	96	1	2	26	67	5	27	0	0	0	1	0	1	32	100
North Texas	164	456	27	0	37	178	0	21	0	0	0	0	0	1	74	101
Panhandle	9	97	3	2	12	67	12	3	0	0	0	1	0	1	23	30
South Texas	120	267	5	4	64	135	16	39	0	0	0	3	0	7	63	83
Border Co	31	65	6	0	23	60	0	5	0	0	1	0	0	2	31	61
West Central	80	155	20	0	56	72	1	43	0	0	0	0	1	2	42	36
West Texas	74	318	18	0	38	242	6	17	4	0	1	7	1	22	147	419
Utah	6	2	0	0	8	0	0	2	0	0	0	0	0	0	18	3
Wyoming	19	58	4	0	7	36	0	8	0	0	0	0	1	1	37	71
Totals: Jan.	766	2,636	108	31	673	1618	197	479	4	2	14	14	26	85	878	2316
Feb.	798	2,931	93	30	630	1745	144	548	4	7	17	22	34	126	877	2402
Mar.	1040	3,535	91	41	674	2133	219	623	4	11	16	26	19	107	863	2534
April	957	3,135	111	19	556	1819	159	525	6	4	8	28	9	102	882	2551
1955 Total	3561	12,237	403	121	2533	7315	719	2175	18	24	55	90	88	420	...	...

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Exploration

CALIFORNIA

★ Union Oil Company has completed two new producers in the recently discovered Bourdieu pool southeast of the Guijarral Hills field in Fresno County. Bourdieu 75-1 was completed for initial production of 1255 bbl per day of 29.9 deg crude oil, from a perforated interval 10,730 to 10,850 ft. Sanger 44-1 was completed flowing 899 bbl daily of 29.9 deg crude. Union has 1600 acres under lease in the area and two more wells are currently drilling in the vicinity.

★ Atlantic Oil Company and M J M & M are preparing to drill Jeppi No. 5 on Sec. 17, 30-29, a southerly extension test of the Jeppi Camp pool in the Edison field of Kern County. The well is expected to go to around 6000 ft to test the Jewett-Pyramid Hill sands.

LOUISIANA

★ Offshore marine wildcat of Continental Oil Company has been completed in the West Delta Area of Plaquemines Parish, Block 56. The State Lease 2550 No. A-1 was finished at a plug-back depth of 4373 ft after an original total depth of 12,898 ft. At 6052 ft 10¾-in. casing had been set. Initial potential gaged a flow of 2 bbl of 52 deg condensate and 689,000 cu ft of gas through a 9/64-in. choke. Tubing pressure was 1710 lb.

★ John W. Mecom, Freeport Sulphur Company and the Placid Oil Company have opened up a new producing zone and one-mile extension of the Lake Washington oil field of Plaquemines Parish. The well is the No. 1 Louisiana Land and Exploration Company Unit A, which tested a flow of 270 bbl of 31 deg crude from perforations in casing between 13,978 and 13,990 ft. Flow was gaged through a 10/64-in. choke. Location of the well is about 5½ miles southwest of Port Sulphur.

NEVADA

★ Shell Oil Company announced a new development well will be drilled at its Eagle Springs oil production site 65 miles southeast of Ely. It will be drilled close to Shell's 35-35 development well placed in production recently with an initial output of 540 bbl daily. Shell has two wells on production at the site.

PERU

★ Douglas Oil Company has successfully completed its first deep test in the Lobitos area of Peru. The well came in flowing 720 bbl of 39 deg oil through a 18/64-in. choke. It was directionally drilled under the ocean from onshore location and was completed in the Basal Salinas zone in an interval between 6896-6963 ft.

CANADA

★ In the South Sturgeon field, Alberta, Union Oil Company and Hudson's Bay Oil & Gas Company have completed Liberal 7-31 flowing at the rate of 3960 bbl daily of 38 deg crude from a depth of 8568 ft. In the same area, Liberal 5-31 was completed for an initial rate of 1900 bbl daily from 8431 ft. The two companies now have six producing wells on the Liberal Block where their discovery well was completed eight months ago for initial production of 4476 bbl per day of 38 deg oil.

NEW MEXICO

★ Sunray Mid-Continent, et al, have a new discovery in Lea County. The well is the East Bagley Unit No. 1, which has had good showings on drill-stem test at approximately 10,000 ft. The test revealed a well saturated oil sand and some 1500 ft of oil was recovered. SDX will drill ahead to test the Devonian below 10,500 ft.

★ An Enid, Oklahoma operator, Joe N. Champlin, has opened a new field with his Featherstone-Federal No. 1, in sec. 6-14s-33e of Lea County. Total depth of the well is 9951 ft, with casing perforated in the Permo-Pennsylvanian at 9929-49 ft. Two hour flow of 63.5 bbl of oil with small show of water came through at 23/64-in. choke.

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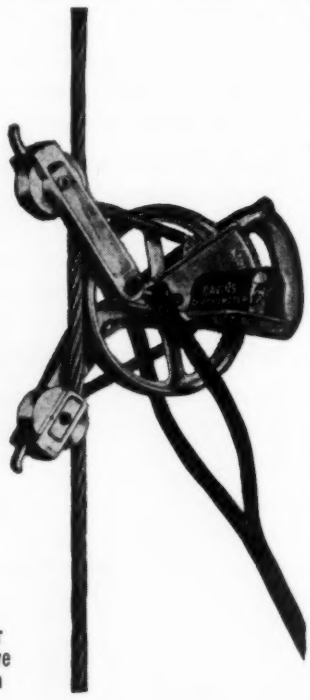

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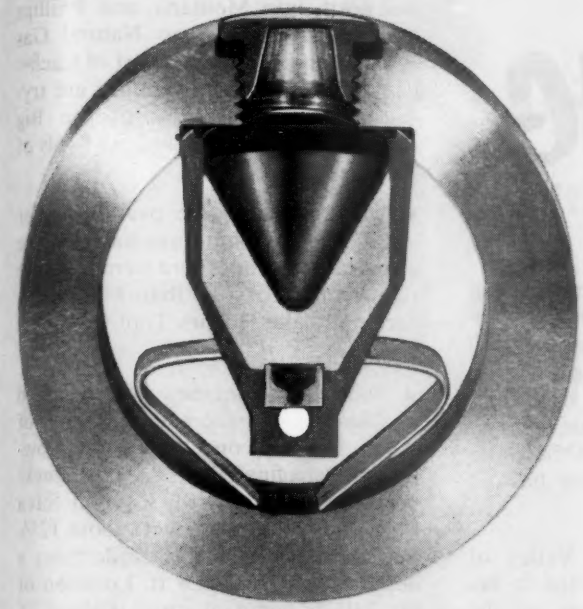
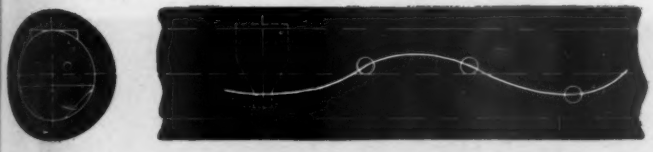
WESTERN'S NEW ROCKET JET GUN...



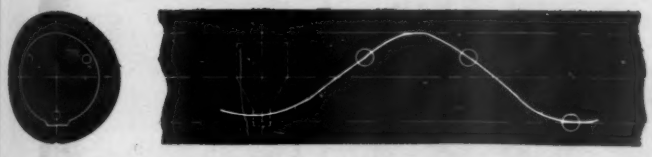
here's the how...

New WESTERN ROCKET Jet perforating principle through use of spring device in charge positioning brings you more effective application of jet force to target.

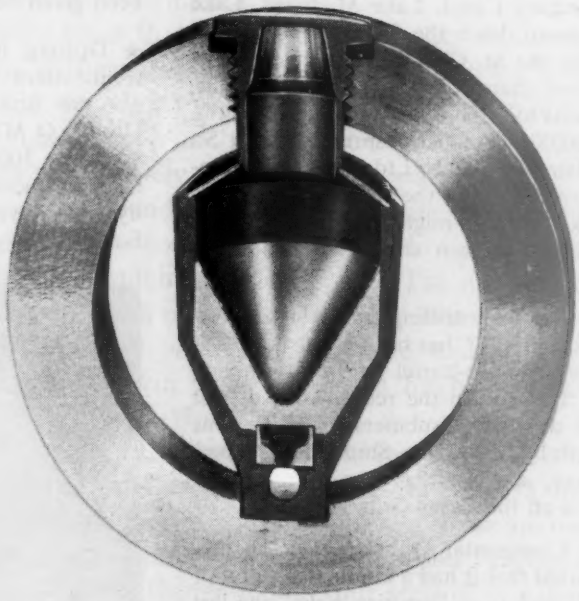
By shortening prima cord length as shown in "A" below, charge-to-charge interference has been eliminated thus allowing use of a larger charge for more effective jet perforating.



(A) ROCKET JET GUN



(B) STANDARD JET GUN



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Western's new engineering principle of charge positioning* in tubular jet guns brings you three major perforating advantages:

1. WESTERN ROCKET Jet Gun through charge placement provides more effective use of jet force.
2. WESTERN ROCKET Jet Gun through shortening of prima cord allows use of larger charge than standard.
3. WESTERN ROCKET Jet Gun provides superior perforating effectiveness with sureness of penetration and safety provided only by retrievable guns.

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What's doing in DRILLING

★ Wherever Texans go, they usually manage to take a little bit of Texas with them. In this case, Houston contractor Harold L. Strader is taking a 122 by 32-ft drilling barge with him to Canada. It will be towed from Texas to New Orleans, up the Mississippi and Illinois rivers, through the Chicago Sanitary Canal, Lake Michigan, Lake Huron, down the St. Clair River and into the St. Clair Lake, a distance of more than 1200 miles. He has contracts to drill 10 exploratory wells on a 100,000-acre lease spread of the St. Clair Gas Fields, Ltd., a Toronto concern, all along the south shore of the lake. As you might have guessed, the barge has been christened the "Lake St. Clair."

★ Another drilling barge, the "Vermillion Bay," has been constructed for the Brewster-Bartel Drilling Company of Houston in the record time of just 31 days. The submersible barge was built by Levingston Shipbuilding Company, and is already on its first location off the Texas Gulf Coast.

★ Continental Oil Company has reported that it had a cumulative total of 475,981 ft of "working hole," the last week in May. This is "cut up" into 76 drilling wells, incidentally.

★ Souris Valley Oil Company, Ltd., a Manitoba company, has resumed operations on several blocks in southwestern Manitoba. At present, the company with Anglo-Canadian Oil Company is drilling the Shannon No. 1 22. Progress on this well was halted following cementing of the surface casing on April 2 due to the road ban. This well is located in Lsd. 1, 22-2-28 W 1. Other locations to be drilled by this pair include four tests in the vicinity of the Pierson field.

★ Souris Valley will drill nine wells this summer along the general trend running from the Alida and Nottingham producing areas of Southeastern Saskatchewan, including the wells in the Pierson area in Manitoba, to the Westhope pool of Bottineau County, North Dakota. Production has already been obtained from one well in this trend.

★ Texaco Exploration Company will try a new system of drilling in the Pembina area of Canada, whereby several wells will be directionally drilled from one location. Muskeg, mud conditions and resultant road bans stymie rig moving in the spring months. Official information on the new method has not been given out by Texaco.

★ Drilling in the Cache Valley of southeastern Idaho is expected to begin the first of this month by the Double O Mining and Timber Group who have 3000 acres in the area. There is no production anywhere in the vicinity and as yet there are no pipe line facilities.

★ Nearest drilling activity to Double O's proposed wildcat is the Beaverhead No. 1 Livestock, about 200 miles to the north into Montana, and Phillips Petroleum and El Paso Natural Gas projects about 150 miles east of Cache. The latter mentioned ventures are trying northern extensions of the Big Piney and Tip Top oil and gas pools of Colorado.

★ The road bans are over now, for awhile anyway, and Canadian rigs are again moving out. There were 52 more rigs running May 23 than May 9, according to the Hughes Tool Company reports.

★ Most important news of any kind to come out of the southern part of Africa recently concerns a good showing in Petrofina's well in Portuguese West Africa. The well, Captain Silva Carvalho No. 1, has flowed about 12½ bbl per hour of 30 deg crude from a depth of 8397 to 8528 ft. Location of the Belgian company's well is about 25 miles south of Luanda, Angola. Site is near the coast, where there is a thick Cretaceous-Tertiary series laid upon a pre-Cambrian basement complex that is exposed a few miles inland.

This Is Drilling? An activity which gained popularity as an unusual sport is now proving its worth as a useful tool of industry. L. E. Borgman and B. M. Krieger of Shell Oil Company are shown checking their diving gear before going down in 48 ft of water off the Texas coast to check the Gulf floor beneath the big mobile drilling platform, "Mr. Gus." On their upper bodies the divers are wearing porous rubber jackets as protection against the cold. They are holding an air cylinder which provides the underwater air supply. In left foreground is a water-tight face mask, and at right are swim fins. Shell's oceanographers and engineers have learned skin diving techniques to make observations and measurements of currents, soil conditions, corrosion, sand abrasion and other factors which affect the location and operation of the ever-increasing fleet of offshore drilling rigs.

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Drilling

★ Although Conoco does not have any wells drilling in the states of Nevada, Oregon, and Washington, its president, L. F. McCollum has ventured to say that oil will eventually be found in these areas. Conoco has geologists busy in all three states and holds leases on 100,000 acres in Nevada alone.

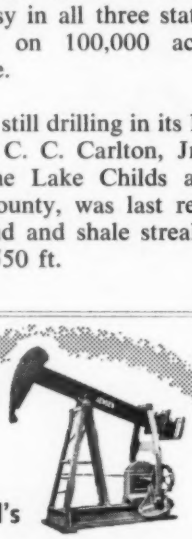
★ Conoco is still drilling in its Florida wildcat. The C. C. Carlton, Jr. et al No. 1, in the Lake Childs area of Highlands County, was last recorded coring in sand and shale streaks at a depth of 12,550 ft.

Oil company representatives from South Louisiana visited the test well of Otis Engineering Corporation, manufacturing affiliate of Otis Pressure Control, Inc., last week to observe a functional test of a new type of tubing safety valve. The device combines the operating features of the Otis surface safety valve and the Otis "storm choke." Shown above from left to right are C. E. DeWitt, with the Shell in Franklin; George Grimmer, Otis, New Iberia; A. Goodrich, Texas Co., New Iberia; Gordon Nunn, Tidewater, Lafayette; Bill Hill, division manager for Otis in New Iberia; Keith Ebner, Texas Co., New Orleans; A. R. Newman, Shell, Franklin; Carl Ivey, Otis test engineer, Dallas; Dick Anderson, Sun, Lafayette; Lowell Wilhoit, vice-president for sales and service, Otis, Dallas; Kenneth Robbins, service office manager for Otis, Dallas, and Phil Sizer, Otis design engineer, Dallas, who is explaining the equipment.

★ Universal Consolidated Oil Company has completed its fifth and most prolific well on the Twentieth Century Fox studio property in the new West Los Angeles pool. The well was completed at approximately 7200 ft and flowed at the rate of 840 bbl per day of 24 deg oil through a 18/64-in. choke. Other wells completed on the studio property, in the same zone, have indicated potential production of 525 bbl per day and 750 bbl per day respectively. All five completed wells on the 260 acre lease are shut-in awaiting completion of a pipe line to transport production to tank storage.

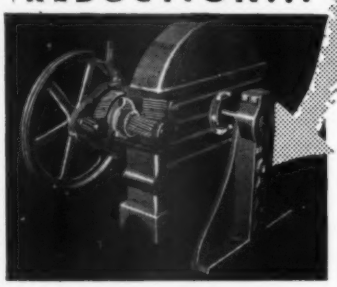
★ Standard Oil Company of California has spudded two new wells in the city of Taft, in Kern County. No. 57, 13 C, near the community hospital, is drilling ahead below 8235 ft. The later start, No. 45, 13 C, located near the community plunge, is a shallow test for production in the Calitroleum sand which is so prolific in the Midway-Sunset field.

★ Intex Oil Company's No. 13 on Sec. 29-21 on their 320 acre Cymric lease has been perforated in a 30-ft interval of the Oceanic sand below 4520 ft. On a test it surfaced fluid in 4½ minutes with a 200-lb flow pressure. Intex already has 14 producing wells on the lease and indications are that this latest may be the best of the lot.



JENSEN's

DOUBLE GEAR REDUCTION...



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Annual Index for 1954 *The Petroleum Engineer*

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★ The sixty-or-so rigs that have been running in a five-mile radius of Sherman, Texas, for the past few months have created new jobs, capital and certainly a lot of good will for the oil industry. So much so that the townspeople complimented the oil people with a "Cel-Oil-Bration" bringing in Texas Railroad Commissioner E. O. Thompson and Director of Defense Mobilization Dr. Arthur S. Flemming to pat the oil men on the back. Grayson County, in the heart of the Sandusky field, exceeded all other Texas counties in the number of wildcat producers last year. Only Andrews County exceeds this county in active rigs at the present time, according to Hughes Tool records.

★ Archer Oil Company has announced the ownership of a royalty interest in a 2000-acre block of leases in the Sespe area of Ventura County, which has been leased to David Gladstone and several associates. Intensive geological work has been conducted in the area and Gladstone is expected to initiate a drilling job in May.

★ Reserve Oil and Gas Company has completed Reserve-Pauley 12-34, a one-half mile extension well in the central area of the Tejon-Grapevine field. The well was completed in the Jewett sand, flowing at the rate of 724 bbl per day of 35.6 deg oil from an interval 7190 to 7267 ft.

★ The combined drilling operations of Sunray Mid-Continent Oil Company, incident to the merger of Sunray and Mid-Continent and the combination of the two companies' exploration and production departments, give the company a total of 40 drilling operations underway. Sunray Mid-Continent is operating 31 of the drilling projects and the others in which Sunray Mid-Continent has an interest, are being operated by other companies.

★ Trans-Tex Drilling Company, a subsidiary of Husky Oil Company, Cody, Wyoming, will establish new headquarters at Shreveport, Louisiana. The firm has had its offices in Longview, Texas.

★ Cron and Gracey Corporation, Houston, Texas, drilling firm has been purchased by John W. Mecom, also of Houston. Mecom is known for his several wells that have exceeded a depth of 15,000 ft. Mecom, with Freeport Sulphur and Placid Oil, has just finaled one that went past the 15,500-ft mark. This particular well opened up a new producing zone in the Lake Washington field of Plaquemines Parish, Louisiana. This well, the L L & E Unit A No. 1, flowed 270 bbl per day of 31-deg oil from perforations in casing at 13,978-90 ft.

Rotary Rigs Operating in Oil Fields of United States and Canada*

	Apr. 18	Apr. 25	May 2	May 9
Pacific Coast	155	157	152	147
Oklahoma	324	320	357	347
Kansas	180	191	194	195
Rocky Mountains	207	202	209	221
Canada	118	105	85	77
Ark-La-Tex	170	162	160	164
West Texas and New Mexico	504	500	517	534
Gulf Coast	587	581	563	571
Illinois	132	152	143	173
North Texas	356	361	361	353
	2733	2731	2741	2782

*As reported to the American Association of Oilwell Drilling Contractors by Hughes Tool Company.

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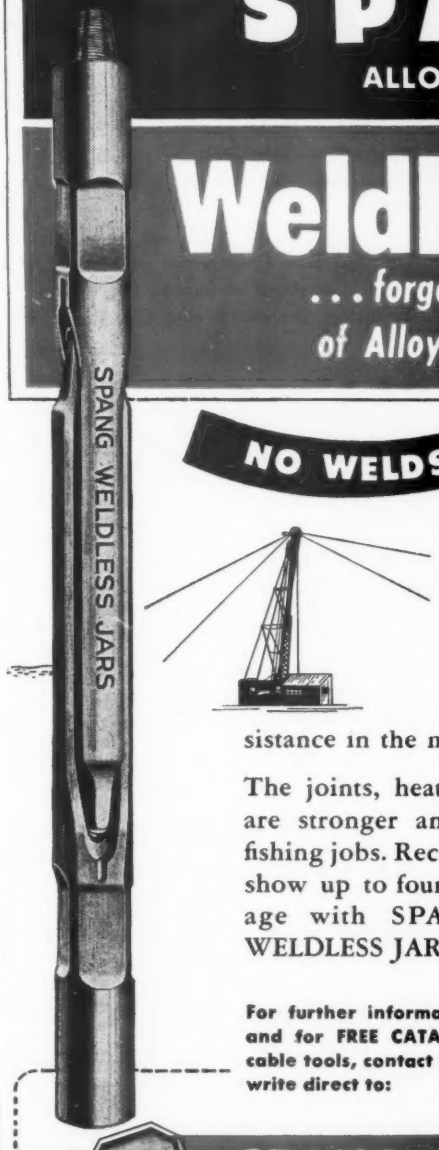

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RUNNING TOUR with MEN in the INDUSTRY

▸ **Richard L. Porter,** formerly district geologist of the Houston geological office, has been moved to position of district landman in the newly created Beaumont district of Sinclair Oil & Gas Company. **Leo M. Wright** has been promoted to the position of district geologist of the Houston geological office.

▸ The directors of Sunray Mid-Continent Oil Company have elected **F. W. (Dick) Borden,** Los Angeles, California a vice president of the company and manager of the company's West Coast district operations. Borden joined the company in 1930, serving as a roustabout, pumper, gager, and field clerk in various California areas until 1933, and by 1948 had risen to the post of California production superintendent, and in May, 1952, was appointed manager of the California district, on transfer of Sunray's Vice President R. E. (Ed) Foss of the Tulsa general offices as manager of production.

▸ **Everett A. Jenkins** was elected executive vice president of Three States Natural Gas Company at a special meeting of the board of directors in Dallas. Jenkins' elevation was announced by **J. A. McGuire,** president of Three States, following the meeting. Jenkins joined Three States a year ago as vice president for exploration and development after 28 years as general superintendent of Skelly Oil Company. McGuire also announced that **James D. Cooper** had been promoted to superintendent of production following Jenkins' shift.

▸ **Hugh W. Curfman,** formerly assistant regional geologist for the Sun Oil Company, has ben named district geologist for Southern Production Company, Inc., at its newly-opened district office in Lafayette, Louisiana. Curfman, a graduate of the University of Texas, was with Sun Oil Company for more than seven years, four of which were spent in Beaumont, Texas, and the last three in Lafayette.

▸ Buffalo Oil Company has announced the appointment of **G. R. Carter,** as new division manager operating out of Midland, Texas. **W. W. Lomerson** is new regional manager of the company's southern region with offices in Fort Worth.

R. I. Dickey

▸ **Robert I. Dickey** has been elected vice president, exploration, and a director of Texas Pacific Coal and Oil Company. Dickey joined Texas Pacific's exploration department in a management capacity on April 1. Previously, he had been vice president of Forest Oil Corporation, Midland, and with Stanolind Oil and Gas Company.

▸ **Paul L. Lyons** has joined the Sinclair Oil and Gas Company as chief geophysicist. Lyons, who is currently president of the Society of Exploration Geophysicists, has been for the last three years manager of exploration and production for Anchor Petroleum Company. He has served with Humble and Carter prior to joining Anchor.

Officers and Chairmen have been elected for 1955-56, Pacific Coast District, Division of Production, American Petroleum Institute. These are: from left to right (standing), Irv Dagan of Standard Oil Company of California, vice chairman, Coalinga-Kettleman; John Bell of Humble Oil & Refining Company, vice chairman, Advisory Committee; H. H. Carrick, Jr., of General Petroleum Corporation, vice chairman, Los Angeles Basin; J. J. Oliphant of General Petroleum Corporation, vice chairman, San Joaquin Valley; Don Sweet of Richfield Oil Corporation, vice chairman, Coastal Area; (seated) Sam Grinsfelder of Union Oil Company, vice chairman, Advisory Committee; O. A. Graybeal of Sunray Oil Corporation, chairman, Pacific Coast District; Mrs. Elsie Edmiston, secretary; and Charles T. Reichert of National Supply Company, treasurer.

▸ **C. B. Wentz, Houston,** has been promoted to assistant manager of Continental Oil Company's southern region. Formerly manager of the company's headquarters coordinating and planning department, he will continue to make his headquarters at Houston.

E. A. Austin, Houston, has been promoted to manager of production for the company's southern region. Formerly assistant regional production manager, he will succeed **Hal F. Nabors,** who recently was promoted to assistant manager of Conoco's central region at Oklahoma City. Austin joined Conoco in 1939 as a roustabout at Tepetate, Louisiana, and has held a variety of producton positions at Tepetate and Ville Platte, Louisiana, and Rincon, Texas.

▸ **Frank Goldstone** has been named manager of the newly-created exploration section of Shell Oil Company's technical services division in Houston, Texas. Goldstone, a veteran of 33 years with Shell, has been serving as assistant manager of the division. **Joseph Chalmers** will be manager of the division's production section, and will continue to handle administrative functions affecting both the production and exploration sections.

Appointment of **John W. Pittman** to succeed **E. N. Van Duzee** as production manager of Shell Oil Company's New Orleans exploration and production area has been announced. Van Duzee is being transferred to the Midland, Texas area to be production manager there. Pittman returns to Louisiana after a year on special assignment in the production department in the company's head office in New York. Before going to New York he was acting production manager in New Orleans.

▸ **R. M. Churchwell** of the Ohio Oil Company, Casper, has been elected chairman of the Rocky Mountain district of the American Petroleum Institute's Division of Production. He succeeds **H. B. Gernett** of the Trigood Oil Company, Casper.

Six state vice chairmen for the district also were elected. They are: **George Goodin,** Petroleum Information, Casper, for Wyoming; **Roy Fuller,** Amerada Petroleum Corporation, Williston, for North Dakota; **Ray Wright,** Sinclair Oil and Gas Company, for Colorado; **R. E. McMillen,** Ohio Oil Company, Sidney, for Nebraska; **R. W. Gemmer,** Carter Oil Company, Billings, for Montana; **L. S. Fuller,** El Paso Natural Gas Company, Salt Lake City, for Utah. **Richard Armstrong** of the Oil Well Supply Company, Casper, was named district secretary-treasurer.

▸ **Malcolm G. Baker** has been named supervisor of the interpretation subsection, geophysics section, geological department at Caracas by the Creole Petroleum Corporation. The company has also announced **A. O. Settar** as the new joint interest coordinator in the production department at Caracas.

▸ The degree of Doctor of Philosophy, *honoris causa,* will be conferred this month on **Dr. Beno Gutenberg,** professor of geophysics and director of the Seismological Laboratory of the California Institute of Technology, by Uppsala University, Sweden. He is a member of many American and foreign societies, including the National Academy of Sciences, and past president of the International Association of Seismology and Physics of the Earth's Interior.

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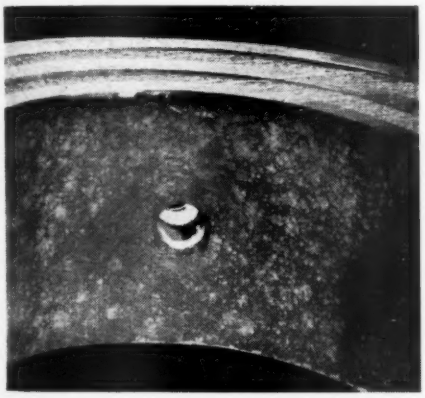
New Burrless Cap for Ogival Bullet Provides Burr-Free Penetration

The new Burrless Bullet Cap is an exclusive McCullough feature. Inserted over the point of the improved ogival bullet at the time the perforator is loaded, it provides a completely burr-free hole on the inside surface of the perforated casing. Depth of penetration is not affected. Burr-free holes reduce the need for subsequent scraping and insure free passage of swabs, packers or other close fitting tools.



Unretouched photo above shows three string penetration by ½" Ogival Bullet with exclusive McCullough Burrless Bullet Cap. Note smooth, burr-free inner surface of pipe.

New Bulletin Available on M-3 Guns

This four-page, illustrated bulletin, No. 203, describes recent improvements in M-3 Bullet Perforator design and introduces the new, deeper penetrating Ogival Bullets. It gives specific examples of increased firing power and deeper penetration as experienced in competitive tests. Advantages, general characteristics, sizes, etc. are also given.

Request Bulletin No. 203 from McCullough Tool Company, 5820 South Alameda Street, Los Angeles 58, California.

Deeper Penetration Increases Production 2700 B/D

McCullough M-3 Bullet Guns Perforate 411 Feet of Pay Zone to Increase Production 245%

Excellent results obtained by the improved M-3 Bullet Perforator were dramatically illustrated by a recent field report from McCullough's Bakersfield Branch area.

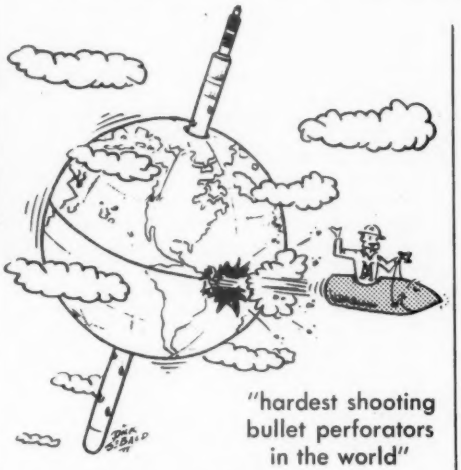
M-3 Guns firing improved Ogival Bullets perforated 411 feet of oil zone for a 2700 B/D increase in production.

This well had previously been perforated by another service company for 1100 barrels per day. However, the operator believed better production was possible and called McCullough to re-perforate.

McCullough Service Crew made 17 runs with 3½" O.D. double 20-shot M-3 Guns, 14 runs with 3½" O.D. double 10-shot M-3 Guns and 8 runs with 3½" O.D. M-3 Guns one shot every two feet—a total of 39 runs in 39½ hours rig time.

A total of 1,000 improved ½" Ogival Bullets were shot in 5" O.D. 15 lb. cemented casing between 10,565' and 10,976'. Production increased from 1100 to 3800 barrels per day—a 245% gain.

Results like this can only be obtained by deepest penetration—penetration that reaches far out into the pay zone; exposes more productive formation; gets more oil—the kind of penetration you get only from McCullough M-3 Bullet Perforators.



"hardest shooting bullet perforators in the world"

McCullough Opens Two New Branches In Mountain Area

McCullough Tool Company has just opened new service branches at Westhope, North Dakota and Grand Junction, Colorado.

Both branches are fully equipped to render all McCullough wire line and fishing tool services to the rapidly expanding oil industry of the Rocky Mountain area.

Experienced crews, dependable equipment and skilled service are available on a twenty four hour basis.

McCullough M-3 Outshoots Premium Bullet Guns

In a very recent series of competitive tests, set up and supervised by a major oil company, regular improved McCullough M-3 Bullet Perforators outshot the premium priced guns of two other service companies. Here are the results:

	Average Penetration into Special Targets
McCullough	5¼"
Company A	4⅜"
Company B	4⅛"

McCullough® TOOL COMPANY

LOS ANGELES
HOUSTON
EDMONTON

To obtain more information on products advertised see Page E-43

B-135

Running Tour

Jack Cashell, of the Preston Oil Company, Columbus, Ohio, has been elected chairman of the Eastern District Division of Production of the American Petroleum Institute for the coming year. Eight vice chairmen were also elected to serve with Cashell. They are: **James M. Bird,** Bird Well Surveys, Bradford, Pennsylvania; **Ralph N. Burns,** Chartiers Oil Company, Pittsburgh; **W. B. Maxwell,** United Fuel Gas Company, Charleston, West Virginia; **Richard J. Murdy,** New York State Natural Gas Company, Pittsburgh; **Fred C. Newman,** Old National Bank, Evansville, Indiana; **S. B. Plummer,** Hughes Tool Company, Mt. Pleasant, Michigan; **Douglas Rogers, Jr.,** South Penn Oil Company, Bradford, Pennsylvania; and **N. E. Trumbull,** Ohio Fuel Gas Company, Terre Haute, Indiana. **Lysle R. Kirk,** Ohio Oil Company, Columbus, Ohio, was elected district secretary-treasurer. The new chairman of the district advisory committee is **Paul G. Benedum,** president of the Hiawatha Oil Company, Pittsburgh. Benedum served as district chairman during the past year.

R. R. Von Hagen, Lloyd Corporation president, was elected president of the Oil Producers Agency of California at the annual meeting. Von Hagen, who succeeds **R. A. Grant,** has been a director of the independent oil group for several years, and was a vice president prior to his election as president.

L. R. Seaman, executive vice president of Intex Oil Company was elected president of the San Joaquin Oil Producers Association at the organization's annual meeting in Bakersfield. Seaman succeeds **E. E. Pyles,** vice president of Monterey Oil Company, who has served in that capacity since 1948. **H. F. Owen,** Berry Oil Company and Berry Holding Company, general manager was re-elected first vice president. **E. C. Reid,** Gene Reid Drilling Company, Inc., president, was elected second vice president and **Charles Premo** was again named secretary-treasurer. The entire directorial board was re-elected.

A. M. Shook

Promotion of **A. M. Shook** to division petroleum engineer of South Texas division, The Texas Company's producing department, has been announced. He succeeds **W. F. Herbert,** who was transferred to foreign operations. Shook is a graduate of Texas A&M College and joined The Texas Company as a roustabout at Pierce in 1937. He has served as acting division petroleum engineer, Houston, since last November.

Wilton E. Scott has been appointed manager of exploration in the production division of Tennessee Gas Transmission Company. He has worked for Jersey Standard and Cities Service and in 1954 he was elected a vice president of Buffalo Oil Company and placed in charge of all exploration in the firm's Midland area. He also was elected a vice president of Maljamar Oil and Gas Corporation, a Buffalo Oil associate. He recently resigned from Buffalo Oil Company to join Tennessee Gas, and has moved from Midland to Houston to assume his new duties.

George Stetson

Clyde Johnson

Delta Gulf Drilling Company, Dallas, Texas, has named **George Stetson** as chief engineer with headquarters in Houston. Stetson has been associated with the Offshore Company at Baton Rouge, Louisiana.

Delta also has announced the appointment of **Clyde Johnson** as vice president and manager of its two Venezuelan subsidiaries, Perforaciones Delta C. A. and Perforaciones Guarico A. A. He has had extensive experience in Latin American countries, particularly Venezuela, having been with Loffland Brothers Company of Venezuela prior to his affiliation with Delta.

John L. Walker, gang pusher in Magnolia Petroleum Company's Luling district, has been promoted to assistant foreman and moved to the company's Alice district. **Willie L. Jones,** assistant foreman in the Alice district, has been transferred to the Luling district. **James A. Reedy,** gang pusher in the Luling district, has been promoted to assistant foreman. **Robert K. James,** senior petroleum engineer at Houston, and **H. G. Walker,** petroleum engineer at Alice, are being transferred to Socony Mobil Oil Company, Inc., to be assigned duties with the Iran Consortium.

Robert E. Ritchie, petroleum engineer in Magnolia's Rodessa producing district, has been moved to the company's Brownfield district in West Texas. **Doyle G. Marrs,** petroleum engineer at Drumright, has been transferred to the Vanderbilt producing district replacing **James H. Berry, Jr.,** who has been transferred to Drumright. **LeRoy Radford,** petroleum engineer at Drumwright, Oklahoma, has been transferred to the West Texas division offices at Midland, Texas. **Marshall C. Gulledge, Jr.,** petroleum engineer in the Brownfield office has also been transferred to the West Texas division offices at Midland. **Luther W. Randerson,** senior petroleum engineer at Midland, has been moved to the Gulf Coast division office at Houston.

Norvan E. Bourland, petroleum engineer at Alice, has been promoted to district petroleum engineer at Wewoka, Oklahoma. **Glen W. Barb,** district petroleum engineer at Wewoka, has been moved to the Vanderbilt district in the same capacity. **Byron O. Sims, Jr.,** petroleum engineer in the Brownfield district, has been promoted to district petroleum engineer of the Natchez producing district. **John D. Howard,** district petroleum engineer at Vanderbilt, has been transferred to the Falfurrias district in the same capacity. He replaces **J. L. White, Jr.,** who has been transferred to the producing department as foreman at Falfurrias. **Charles F. Underriner,** district petroleum engineer at Natchez, has been moved to the Electra district in the same capacity. **A. H. Massad,** assistant division petroleum engineer at Houston, has been promoted to division petroleum engineer and assigned to the Louisiana-Gulf division with headquarters at Morgan City, Louisiana.

A southeastern division of Drilling and Exploration Company, with headquarters at Monroe, Louisiana, has been formed and will be managed by **H. D. Pyke,** formerly manager of the West Texas-New Mexico division at Midland, Texas.

Replacing Pyke as manager of the southwestern division at Midland, is his previous assistant, **Horace P. Goodrich.** Other personnel changes are the addition of **David A. Carnahan,** formerly with Emsco, as chief engineer at Los Angeles; **O. G. Barton** transferred from California to Monroe, Louisiana as drilling superintendent, and **H. J. Stewart** from Los Angeles to The Hague, Holland, as assistant to **M. R. Garrison,** manager of Drilvo, Drilexco's European Dutch subsidiary.

P. L. McLaughlin

Philip L. McLaughlin, former drilling editor of *World Oil,* has been appointed to head the product and drilling research department of Cardwell Manufacturing Company, Inc. In his new capacity he will also direct advertising and sales promotion. A graduate petroleum engineer of the University of Texas, McLaughlin has served with the Ohio Oil Company and Continental Oil Company in several capacities. At present, he is co-chairman of the Southwestern district API study committee on surface mud systems, and has been appointed to several posts on AIME, API, and AADC committees to study air drilling and slim hole drilling techniques.

Organizational changes in eight production department positions in The Carter Oil Company have been announced. **R. E. Hammond,** production staff assistant of Carter's eastern division, Mattoon, Illinois, has been named division production manager. **Irvin Alexander,** Carmi, Illinois, will replace Hammond as production staff assistant. Alexander, a veteran of 34 years with Carter, began work for the company as a roustabout. He has been district superintendent at Carmi since June, 1949.

Other appointments include: **H. W. McCormick,** district superintendent of the Vernal district, Vernal, Utah, to district superintendent of the Carmi district; **B. M. Bradley,** assistant superintendent of the St. Elmo district, St. Elmo, Illinois, to superintendent of the Vernal district; **J. L. Wible,** district engineer of the Jackson district, Jackson, Mississippi, to assistant district superintendent of the St. Elmo district; **R. M. Pitcher,** senior engineer at Magnolia, Arkansas, to district engineer at Jackson; **J. L. Barthel,** acting district foreman at Purcell, Oklahoma, to assistant district superintendent of the Purcell district, and **R. D. Orr,** acting district engineer at Purcell, to district engineer.

Election of **Beverley Matthews,** C.B.E., Q.C., to its board of directors has been announced by The British American Oil Company Limited. Matthews is a partner in the legal firm of McCarthy and McCarthy, a director of The Toronto-Dominion Bank, Brazilian Traction, Light and Power Company Limited and other companies. He is a member of the board of governors of the University of Toronto and a past president of the Toronto Board of Trade.

DIGEST of NEWS and COMMENT ★ ★ ★

Refining . . . Petrochemical . . . Gas Processing

In and Out of Rubber Business? Will Pure Oil and Atlantic sell out of Neches Butane Products Company, biggest makers of butadiene for synthetic rubber? Located at Port Neches, Texas, on the Gulf Coast, this double unit is rated at 100,000 tons of butadiene per annum, equivalent to 135,000 tons of GR-S rubber. A short time ago Neches Butane took over the plant that had been owned by the government. Possible reason for these two companies checking out is that Gulf Oil and The Texas Company, other Neches part owners, have taken over the other two government-owned plants in the southeast Texas rubber district, giving them a preponderance in the area.

★ ★ ★

Oil Company "Real Gone" on Uranium. A century from now and in the interim our national energy demands may exceed our sources and supplies, say The Texas Company and the Canadian N. J. Zinc Exploration Company so the team plans to search diligently in Canada and some places in the U. S. for a supply of uranium.

★ ★ ★

Low-Pressure Polyethylene for U. S. Koppers Company, with myriad arms extending into the chemical industry, will make polyethylene by the new low-pressure Ziegler process developed at the research center of Max Planck in Germany, 'tis said. This polymer is especially high in molecular weight. Small commercial amounts are expected to be available in a few weeks. The product is unusual and is expected to forge into the utilization fields now enjoyed largely by polystyrene. Also, those acquainted with the product believe it will be used widely in applications into which plastics have not yet penetrated.

★ ★ ★

High Temperature Lubricants. New "diesters of fluoroalcohols" organic compounds containing combined fluorine are announced as the latest development for lubricating jet engines and similar equipment. These oils are not decomposed at 500 F, temperatures that break up petroleum-based oils in a short time. Heavier than sea water, they can be used in submarines, as they will not float to the surface when escaping from the sub, thus revealing its location by an oil slick, it is claimed. The discussion was prepared by C. M. Henderson, C. M. Murphy, and Harold Ravner of the Naval Research Laboratory.

★ ★ ★

Oil From Coal? In Colorado. Basing plans on the researches of Dr. F. E. Poindexter and Frank Lowe, St. Louis, Missouri, men Cotarco, Inc. has been organized, with Denver, Colorado, headquarters. The firm plans a $11,500,000 plant in Colorado, in which they expect to recover oils and tars from local deposits. Unit is said to be planned to process 8520 tons of coal per day. It is based on pilot plant results obtained over a period of years, and will not resort to coke oven methods, it is claimed.

★ ★ ★

Big and Little Polyethylene. Super Dylan is the new Koppers polyethylene, one of two unusual ethylene polymer products. The other is a new low molecular weight synthetic wax, supposed to be a suitable substitute for higher-priced special commercial waxes. Super Dylan is a smooth, glossy material like polystyrene, not dull and waxlike; highly resistant to heat, can be sterilized at 250 F without damage, thus is good for nursing bottles, etc. It is also highly resistant to chemicals, even hydrofluoric acid that "eats up" glass like a black boy eats watermelon. It has a high resistance to impact, said to hold this property at temperatures as low as minus 172.4 F.

Eastman Chemicals is making the polyethylene wax, Epolene, expected to be used in improving hydrocarbon paraffin waxes, for packaging materials and by polish makers, wax compounders.

CORRECTION

On page C-55 of the April, 1955 Refining and Petrochemical Edition, an article, "Look to the Infrared Endpoint," written by L. A. Beaudry, was published. The author was credited as being a member of the staff of Standard Oil Company (Ohio), which was in error. The article dealt with a Standard of Ohio plant but the author is a member of the Market Extension Division of Minneapolis-Honeywell Regulator Company.

Polyethylene Process to be Licensed. The low-pressure process for making polyethylene as developed by Phillips Petroleum Company will be licensed, say officials of that company. Phillips Chemical is building a great poly plant near Houston, Texas and will construct a 150,000,000-lb ethylene unit within 50 miles of the polymer unit. This gives another high molecular weight polyethylene source, along with the Ziegler process and product, mentioned elsewhere.

★ ★ ★

Catalytic Muffler to Get More Study. The Houdry catalytic muffler is not yet successful in meeting all problems of stopping hydrocarbons ejected with automobile exhausts, Southwest Research Institute has found. Starting a test series projected for 20,000 miles, the runs were stopped at 10,000 miles because the mufflers were wearing out too fast. More work is being pushed and the Houdry forces believe the difficulties can be cleared in short order. Air Pollution Foundation of Los Angeles, California, fighting smog, is sponsor of the tests.

★ ★ ★

Search Machines for Patent Office. Heartening news for the patent searcher, lawyer, and inventors in general comes with the information that machines are being tried out in the U. S. Patent Office to investigate the voluminous files of patents; the V. Bush Committee recommended that the idea be tried first in chemical patents. U. S. Bureau of Standards is working on, or planning to work out, a machine searching procedure for the Patent Office. Congress will be asked for funds to carry on the work that should result in much less delay in determining the patentability of an idea.

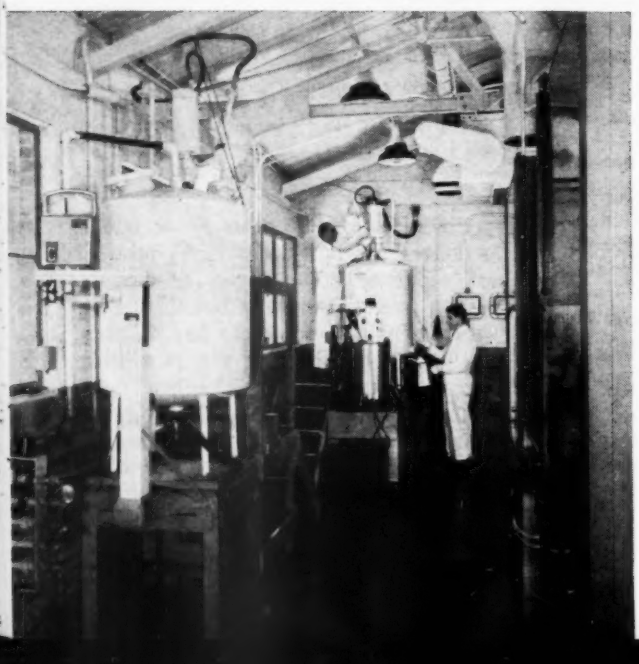
★ ★ ★

M-Xylene for 35 cents per lb. Metaxylene, important aromatic by-product of modern refining, can be bought soon from Oronite Chemical at a price of 30 to 35 cents per lb, it is said. It formerly cost the perspiring chemical manufacturer 75 cents. It will come, in "several million lb" from the preparation unit serving Standard of California's isophthalic acid plant, which goes on stream next October. Xylene can be bought in September.

XUM

Final report on a new reformate process is presented to customer by Ethyl Fuel Technologist Alon Cole. This and other Ethyl Research reports are available to you through the Ethyl Refinery Technologist in your area.

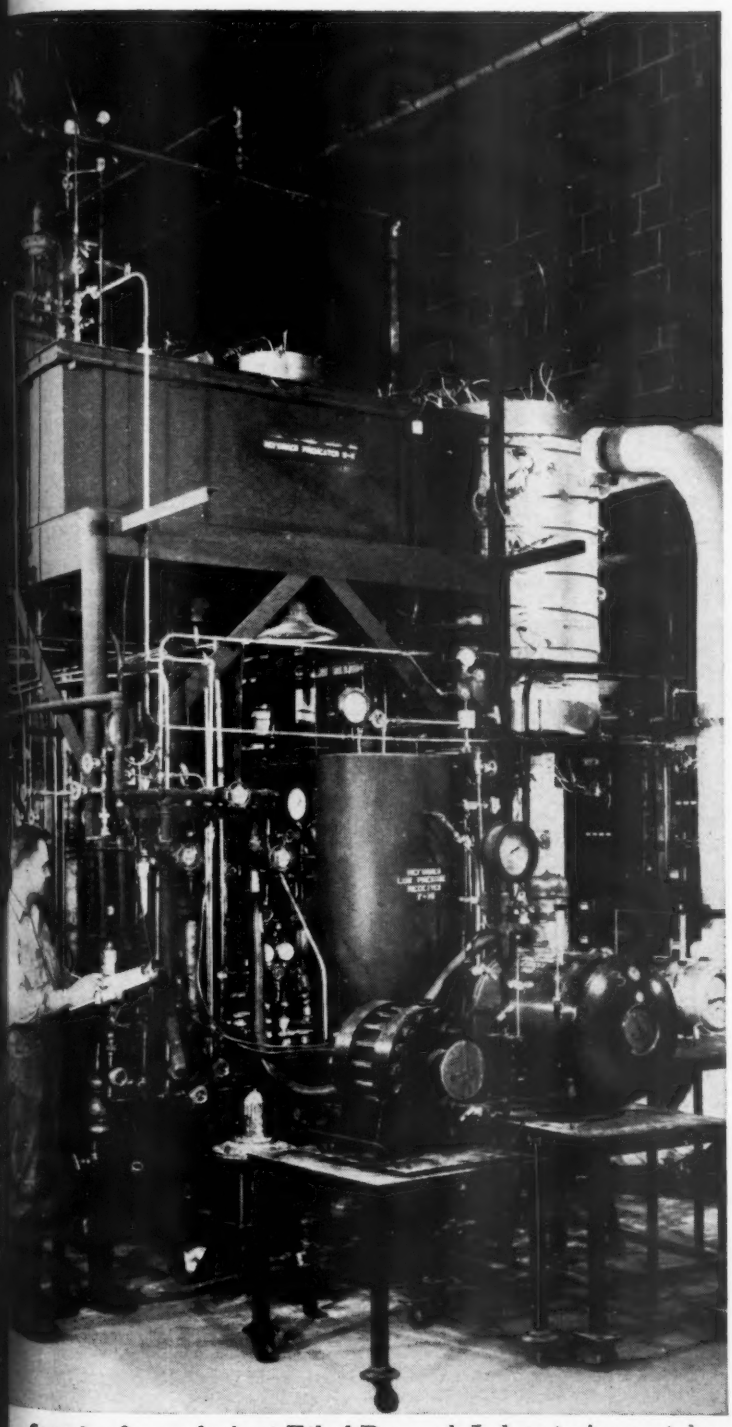
Reformates are blended with various runs of gasoline and tested by Ethyl technicians.



Road testing is performed with various gasoline stocks in Ethyl's highly instrumented controlled-weather rooms.

XUM

New catalytic reformates road-tested by Ethyl Research



Samples for analysis at Ethyl Research Laboratories are taken directly from the pilot plant of the reformate process developer.

In choosing one of the important new reforming processes, or in planning the over-all refinery operations once the plant is on stream, it is vital to know how the reformate will behave in the gasoline to be marketed.

That's where we can help you. Ethyl's Refinery Technology group in Detroit, working closely with the developers of these new processes, has prepared several reports on road antiknock behavior of reformates. And more reports are in process.

Each of these Ethyl reports is based on evaluation of reformate samples from commercial units or from the developer's pilot plant. We blend the new reformates with typical refinery base stocks—straight-run, catalytically cracked, and thermally cracked naphthas—to produce typical gasolines. "Ethyl" antiknock compound is then added, and the gasolines are road-tested on chassis dynamometers in our controlled-weather rooms.

Finally, all the information is collected, evaluated and submitted for approval to the developer of the process.

Reporting to the industry on the behavior of catalytic reformates is another example of how Ethyl is helping serve your needs.

If you have a problem in octane improvement, get in touch with your local Ethyl Refinery Technologist. He'll be glad to work with you.

ETHYL CORPORATION
Research Laboratories

1600 West Eight Mile Road, Ferndale 20, Michigan
2600 Cajon Road, San Bernardino, California

"ETHYL" ANTIKNOCK COMPOUND — ETHYL CORPORATION

News and Comment

Smog-Killing Additive? Science and the industrial chemists of the nation are starting the war on smog on another front, the American Chemical Society was told recently. DuPont Company's Dr. F. S. Arimoto, research chemist, and collaborators told the assembled chemists that a new compound, called DCPI, in very small amounts added to heating oil jet fuels causes the fuels to burn more cleanly, making less smoke. Additive appears to contain iron in some form, and leaves iron oxide in engine cylinders, thus it cannot be used to best advantage in motor fuel until some way is found to eliminate the oxide deposit. This material also shows good effect on anti-knock tendencies.

★ ★ ★

Vapor Pressure Control. A new Reid vapor pressure recorder, it is claimed, enables the operator to monitor the blending of motor gasolines to better results, by enabling the maker to use the most economical percentage of butane in the fuel, so says Precision Scientific about the new recorder. The device is a Standard Oil of Indiana development and that company has licensed P. S. to manufacture and sell it. The unit is said to make in-line blending feasible for small refineries; reduce the number of reblends and makes for TEL savings; records vapor pressure to 0.1 lb, stabilizes within 8 minutes any high or low vapor pressure material delivered to it.

★ ★ ★

Catalyst Plant for Europe. A new cracking catalyst plant is scheduled for Germany by a contract made by Houdry Process Corporation with Chemische Werke Huel, A. G. West Germany, by which the later company will manufacture the catalyst for European needs.

★ ★ ★

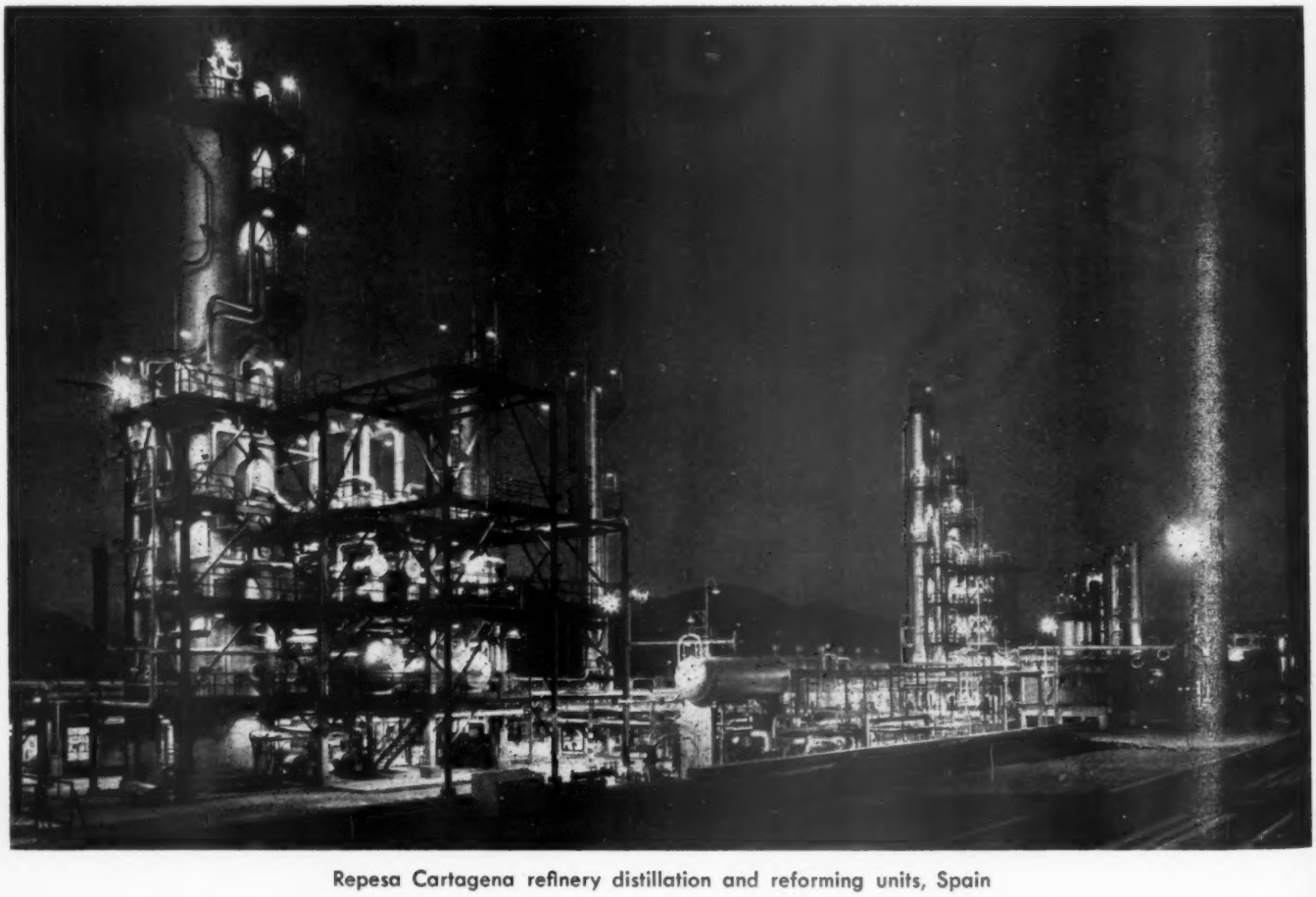
Atomic Power at 6-9 cents per Kwhr? Foster Wheeler Corporation says it is ready to design and build a low-cost atomic energy power plant, to be completed in the next five years or so, in which electric power costs will be as low as the figure range mentioned above. Plant will cost $21 million, produce 100,000 kw; reactor will use a uranyl sulfate "heavy" water solution, going through heat exchangers where fission of U-235 will produce steam at 600 psi. Thorium-232 will refuel reactor with Uranium-233, with more heat and steam as by-product.

And a very few years back, we were taught that the atom is the smallest existent particle of matter!

High-Low Polyethylene. Hard and rough is the road of the synthetic chemical industry! Soon after developing a fairly satisfactory high-pressure, high-temperature polyethylene synthesis process, along comes one Ziegler and upsets the applecart by bringing out the low-pressure, low-temperature process that bears his name. He made a harder, more rigid polyethylene, raising its soft point from 210-220 F to about 240 F. Phillips Chemical Company is proceeding with market research for such a product from its own low temperaure-pressure process; DuPont is making this harder material commercially under the new process principle, so is Carbide and Carbon Chemicals. Monsanto is pushing development work on the same type process and reportedly several other companies are doing the same thing. Verily, the polyethylene processes of today and yesterday will not recognize their own grandchildren.

★ ★ ★

Fluid Coke for Kiln Fuel. Preliminary tests with fluid petroleum coke in cement kiln firing show "encouraging results in California. Permanents Cement Company's plant replaced natural gas fuel with coke, "as received"; will grind to more uniform-sized particles for further tests.



Repesa Cartagena refinery distillation and reforming units, Spain

For Modern Refining

Evaluation of Oklahoma and Kansas Crude Oils

Properties of various Mid-Continent crudes vary considerably, and their properties and possibilities favor different refined products manufacture

J. G. HUDDLESTON and R. E. LINDSAY

CRUDE oils produced in Oklahoma and Kansas are important to a number of refineries in the United States. Efforts to best utilize the new refining processes such as catalytic cracking and catalytic reforming emphasize the importance of feedstock quality. New and increased demands for straight run fractions from crude oil for products such as jet fuel and diesel fuel also place a premium on quality. The yield and character of the crude oil fractions vary widely with different crudes. A comprehensive crude oil evaluation based on a detailed analysis is necessary to best determine the value of these crude oils to the refinery.

Some of the feed preparation units in operation are able to produce large volumes of catalytic cracker feedstock from the portion of the crude represented by the residuum from a Hempel distillation. High vacuum reduction of the distillation residuum provides a means of estimating the quantity of such feedstock potentially available. It also provides a measure of the quality and quantity of reduced residual that a modernized refinery can produce from the crude.

The method used to evaluate the Oklahoma and Kansas crude oils employs fractionation and vacuum distillation to separate the crude oil into fractions similar to those produced in the refineries. Correlations obtained from basic data are used to estimate the behavior of the crude oil and its fractions when subjected to refining processes.

The Bureau of Mines Hempel analysis[2] is used to give the first characterization of the crude oils studied. It also provides a comparative link that permits the crude oil evaluator to extend the results of the more detailed analysis to many crude oils on which only the Hempel analysis is available.

Data and Results

The physical characteristics of the Oklahoma and Kansas crude oils tested vary over a wide range. The API gravities range from 24.2 deg on the Jelinek crude to 50.1 deg on the Elk City. Elk City crude has a low sulfur content of 0.04 per cent and a pour test of —70 F. The Liberal light crude oil is very waxy with a pour test of +70 F. None of the crude oils studied could be called high sulfur crude in the sense that this classification is commonly applied to West Texas and Rocky Mountain crude oils. Crude oil inspection data are shown in Tables 1 and 2.

TABLE 1. Inspection data on Oklahoma crude oils.

Crude oil source	Burbank	West Edmond	Elk City	Golden Trend composite	New Castle	Seminole	West Cement	Floris	Mt. Vernon	Southeast Red Spring
County	Osage	Oklahoma	Beckham	Garvin	McClain	Seminole	Caddo	Beaver	Lincoln	Pottawatomie
Gravity, API at 60 F.	38.4	42.5	50.1	41.9	40.6	40.6	37.5	39.4	40.1	37.3
Reid vapor pressure...	4.7	5.8	9.75	3.8	5.0	4.45	3.0	6.6	5.8	10.2
Vis., SUV at 70 F....	51.11	43.80	<32	41.56	45.08	41.56	52.99	59.18	41.53	48.51
Vis., SUV at 100 F...	41.47	35.49	<32	36.96	38.44	36.29	43.16	44.32	36.99	41.63
Pour point, F.....	+25	−20	<−70	−5	+15	−30	+25	+20	0	+20
Total sulfur, wt. %...	0.25	0.12	0.04	0.23	0.21	0.34	0.18	0.15	0.30	0.48

TABLE 2. Inspection data on Kansas crude oils.

Crude oil source	Davis Ranch	Bemis-Shutts composite	Seeley Wick	West Kansas composite	Norton	Cephas	Jelinek	Feltis, N. W.	Liberal Light	Volkland
County	Wabaunsee	Ellis	Greenwood	Ellis and Russell	Norton	Stafford	Rooks	Barton	Seward	Rice
Gravity, API at 60 F.	28.1	33.5	41.6	36.4	30.5	38.4	24.2	42.4	41.7	48.4
Reid vapor pressure...	0.85	3.8	10.0	2.9	3.7	4.95			6.85	
Vis., SUV at 70 F....	225.4	72.53	38.95	53.50	218.1	45.76	635.3		75.45	
Vis., SUV at 100 F...	123.7	53.02	35.46	44.35	113.7	38.89	303.2	36.3	45.18	32.3
Pour point, F.....	−20	0	−5	−20	+25	+35	<−40	−45	+70	−50
Total sulfur, wt., %...	0.46	0.57	0.20	0.48	0.74	0.28	0.85	0.27	0.18	0.22

A summary of the Hempel distillation data is shown in Tables 3 and 4. Tests on fractions produced by pilot plant distillations are shown in Tables 5 through 12.

Majority of the octane numbers of the 400 F end point unleaded gasolines fall between 40 and 50. One exception is the gasoline from Davis Ranch crude oil, which shows an unleaded octane number of 4.2. This confirms the straight chain paraffinic nature of this gasoline and also shows the effect of the absence of the higher octane light fractions. The Jelinek, Floris, and Elk City crude oils yield comparatively high octane gasolines that approach 60 octane number unleaded. The effect that the undercutting of end points has on the octane numbers is shown by the inclusion of 330 F end point gasoline data.

Data on the 330-400 F boiling range naphthas serve several purposes. As this fraction is frequently charged to reforming operations it is desirable to know the octane number and hydrocarbon type composition. The naphthene contents varied from 24.6 per cent in Davis Ranch naphtha to 70.8 per cent in naphtha from the Bemis-Shutts crude oil. Examination of these naphthas for arsenic or other trace constituents that might poison catalysts would be necessary to completely evaluate this fraction for catalytic reforming. The naphtha fraction from most of these crudes could be used in blending some grades of jet fuel. The naphtha from Davis Ranch crude oil has an exceptionally high freezing point and probably could not be used in jet fuel.

All of the crude oils tested should produce good quality kerosene, straight run burning oils and diesel fuel. One possible exception might be the Jelinek crude which has a low gravity kerosene boiling range fraction. High pour points on the diesel fuel from the Floris and Davis Ranch crudes would prob-

EXCLUSIVE

TABLE 3. Hempel distillation summary, Oklahoma crude oils.

Crude oil source	Burbank	West Edmond	Elk City	Golden Trend composite	Newcastle	Seminole	West Cement	Floris	Mt. Vernon	Southeast Red Spring
Gasoline and naphtha (IBP-392 F)										
Yield, volume per cent	29.9	36.8	55.5	40.3	35.2	39.1	25.1	31.5	37.3	30.5
Gravity, API at 60 F	58.9	62.4	63.9	62.1	62.5	60.2	53.6	60.8	61.8	62.0
Sulfur, weight per cent	0.014	0.009	0.009	0.013	0.016	0.017	0.012	0.009	0.020	0.019
Research octane No.*										
clear	42.0	47.4	56.4	47.4	43.5	43.4	45.6	58.9	50.1	52.8
+ 3 ml. TEL per gal	70.5	71.8	77.8	70.0	70.2	69.0	68.0	80.2	73.0	76.0
Kerosene (392-527 F)										
Yield, volume per cent	17.5	16.0	15.7	9.3	14.5	19.1	20.2	14.0	16.1	14.7
Gravity, API at 60 F	41.7	42.4	41.2	43.2	42.8	40.9	42.9	41.0	40.7	41.8
Sulfur, weight per cent	0.04	0.015	0.03	0.03	0.025	0.11	0.07	0.09	0.09	0.12
Gas oil (527 F to 50 SUV at 100 F)										
Yield, volume per cent	10.8	10.1	6.2	10.3	10.5	7.3	7.0	6.7	9.6	11.0
Gravity, API at 60 F	34.6	35.4	34.5	35.8	35.0	34.1	36.9	35.9	34.5	34.4
Sulfur, weight per cent	0.24	0.11	0.06	0.18	0.12	0.32	0.11	0.13	0.27	0.31
Lube oils (50 SUV at 100 F to 800 F)										
Yield, volume per cent	12.0	14.8	10.8	13.7	11.8	15.1	24.6	15.8	13.6	13.7
Gravity, API at 60 F	33.1-28.5	34.1-28.8	33.8-27.7	34.2-28.7	33.4-27.5	33.0-25.8	36.5-29.1	35.2-29.6	33.2-27.5	32.8-26.2
Sulfur, weight per cent	0.32	0.20	0.10	0.25	0.30	0.37	0.22	0.25	0.45	0.58
Still residue (800 F and heavier)										
Yield, volume per cent	28.6	21.4	10.0	25.9	27.2	18.9	22.8	32.0	21.8	28.0
Gravity, API at 60 F	27.3	25.7	25.6	23.7	22.8	18.3	18.3	25.9	17.6	16.6
Sulfur, weight per cent	0.60	0.26	0.11	0.42	0.43	0.68	0.55	0.34	0.84	1.10
Conradson carbon res., weight per cent	2.18	2.16	1.97	2.75	4.22	4.21	3.50	2.60	7.01	7.51

* Octane numbers determined on IBP—400 F gasoline obtained by separate distillation.

TABLE 4. Hempel distillation summary, Kansas crude oils.

Crude oil source	Davis Ranch	Bemis-Shutts composite	Seeley Wick	West Kansas composite	Norton	Cephas	Jelinek	Feltis Northwest	Liberal Light	Volkland
Gasoline and naphtha (IBP—392 F)										
Yield, volume per cent	15.0	25.8	35.8	30.9	25.3	30.4	12.2	38.9	33.7	51.1
Gravity, API at 60 F	63.1	61.1	63.4	60.7	61.8	59.5	50.6	64.0	61.5	67.6
Sulfur, weight per cent	0.041	0.025	0.010	0.028	0.029	0.006	0.021	0.008	0.011	0.027
Research octane No.*										
Clear	4.2	49.8	49.0	40.2	45.6	46.2	59.1	45.6	49.8	48.1
+ 3 ml TEL per gallon	33.5	73.2	73.0	66.0	69.6	72.0	77.0	72.2	73.4	72.6
Kerosene (392—527 F)										
Yield, volume per cent	14.9	16.1	16.0	17.7	13.2	17.1	15.8	16.1	11.3	15.2
Gravity, API at 60 F	46.2	40.7	42.3	41.3	40.6	41.0	37.3	42.4	42.5	41.8
Sulfur, weight per cent	0.07	0.10	0.03	0.09	0.07	0.10	0.16	0.05	0.06	0.09
Gas oil 527 F to 50 SUV at 100 F)										
Yield, volume per cent	13.0	9.2	9.6	9.5	8.3	10.3	3.5	7.8	9.3	6.2
Gravity, API at 60 F	37.1	33.5	33.8	34.3	33.6	34.5	31.4	35.5	36.8	35.8
Sulfur, weight per cent	0.21	0.20	0.13	0.28	0.37	0.27	—	0.20	0.10	0.28
Lube oils 50 SUV at 100 F to 800 F)										
Yield, volume per cent	9.9	14.8	14.2	15.1	15.7	16.5	23.5	14.6	13.3	11.9
Gravity, API at 60 F	33.8-26.5	32.1-25.6	33.0-28.0	32.6-25.6	32.6-27.8	33.5-28.4	31.1-24.8	34.5-26.2	35.7-31.1	34.5-21.6
Sulfur, weight per cent	0.37	0.55	0.33	0.52	0.58	0.42	0.70	—	0.12	—
Still residue (800 F and heavier)										
Yield, volume per cent	46.2	33.5	21.7	26.1	37.5	34.8	43.0	20.6	30.4	13.6
Gravity, API at 60 F	14.1	15.5	24.2	15.1	12.9	21.3	14.9	17.1	24.3	16.6
Sulfur, weight per cent	0.71	1.03	0.49	1.07	1.39	0.57	1.22	0.88	0.26	0.82
Conradson carbon res., weight per cent	17.45	12.75	5.62	11.63	17.90	6.05	14.90	10.77	3.92	9.98

* Octane numbers determined on IBP-400 F gasoline obtained by separate distillation.

TABLE 5. Inspection data on gasoline and naphtha fractions from Oklahoma crude oils.

Crude oil source	Burbank			West Edmond			Elk City			Golden Trend composite		
Fraction	Gasoline	Gasoline	Naphtha	Gasoline	Gasoline	Naphtha	Gasoline	Gasoline	Naphtha	Gasoline	Gasoline	Naphtha
Boiling range, F	IBP-330	IBP-400	330-400	IBP-330	IBP-400	330-400	IBP-330	IBP-400	330-400	IBP-330	IBP-400	330-400
Yield, volume per cent of crude	23.4	30.8	7.4	31.8	39.5	7.7	48.9	56.8	7.9	30.1	39.5	9.4
Gravity, API at 60 F	64.4	59.8	48.4	65.3	62.0	48.6	66.6	64.2	47.9	66.3	61.8	49.3
Reid vapor pressure	9.1	6.4		9.4	6.3		8.8	8.0		8.8	6.9	
ASTM distillation, F												
Per cent first drop	100	103	329	109	112	327	102	111	340	102	121	321
5	131	137	339	126	137	337	121	126	343	123	138	329
10	152	170	345	146	157	341	136	143	346	142	156	333
30	202	227	353	195	211	348	175	188	353	186	210	340
50	235	264	360	225	250	355	207	225	359	220	246	347
70	265	304	368	253	290	363	235	264	365	247	290	357
90	297	347	382	287	343	376	272	318	380	283	342	373
95	312	363	390	302	363	384	290	345	389	300	361	382
End point	338	383	421	339	387	401	322	378	398	316	385	395
Flash point, TCC, F			110			116			120			110
Freezing point, F			—85			—87			—87			—92
Paraffins, volume per cent	74.7	64.5	38.5	69.4	67.5	45.7	76.4	72.5	41.5	72.8	65.0	42.3
Olefins, volume per cent	0.8	0.8	1.3	0.5	0.7	1.0	0.6	0.6	1.3	0.6	0.7	1.3
Naphthenes, volume per cent	19.8	29.0	51.0	24.4	25.0	42.0	17.6	21.5	44.5	21.7	27.0	46.4
Aromatics, volume per cent	4.7	5.7	9.2	5.7	6.8	11.3	5.4	5.4	12.7	4.9	7.3	10.0
Aniline point, F	135	135	141	135	136	142	134	134	137	137	137	141
Refractive index at 68 F	1.4020	1.4128	1.4360	1.4039	1.4108	1.4373	1.3996	1.4070	1.4389	1.4001	1.4085	1.4350
Total sulfur, weight per cent	0.012	0.014	0.021	0.007	0.009	0.017	0.006	0.009	0.029	0.010	0.13	0.021
Mercaptan sulfur, weight per cent	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<00.01	<0.001	<0.001	<0.001
Doctor test	Sweet	Sweet	Sweet	Sweet	Sweet	Sweet	Sweet	Sour	Sour	Sweet	Sweet	Sweet
Copper strip cor. 3 hr at 122 F	3	2	2	1	1	1	0	0	0	>4	>4	0
Research octane numbers												
Clear	51.0	42.0	25.8	55.2	47.4	20.2	60.3	56.4	25.2	53.9	47.4	22.2
+ 1 ml TEL per gallon	66.3	60.0		66.0	59.2		71.8	66.6		64.0	60.0	
+ 3 ml TEL per gallon	76.5	70.5		76.5	71.8		81.0	77.8		77.3	70.0	

TABLE 6. Inspection data on gasoline and naphtha fractions from Kansas crude oils.

Crude oil source	Davis Ranch			Bemis-Shutts composite			Seeley Wick			West Kansas composite		
Fraction	Gasoline	Gasoline	Naphtha	Gasoline	Gasoline	Naphtha	Gasoline	Gasoline	Naphtha	Gasoline	Gasoline	Naphtha
Boiling range, F	IBP—330	IBP—400	330—400	IBP—330	IBP—400	330—400	IBP—330	IBP—400	330—400	IBP—330	IBP—400	330—400
Yield, volume per cent of crude	11.0	16.1	5.1	21.0	27.5	6.5	28.8	36.4	7.6	23.5	31.0	7.5
Gravity, API at 60 F	67.2	63.1	54.4	65.5	61.1	48.4	66.7	62.2	48.8	64.8	61.0	49.9
Reid vapor pressure	3.6	3.0		9.0	7.9		8.6	7.2		6.6	4.1	
ASTM distillation, F												
Per cent first drop	135	141	311	102	104	310	97	105	319	111	120	314
5	164	172	324	126	127	324	115	131	328	137	155	329
10	181	192	330	146	151	331	134	152	332	156	175	333
30	213	237	341	194	212	340	184	207	338	200	223	342
50	236	275	349	226	255	349	217	249	345	226	259	350
70	261	310	358	252	294	359	247	291	353	256	297	359
90	291	352	372	288	344	376	285	340	367	290	344	374
95	303	365	378	302	362	384	300	357	374	302	362	382
End point	338	377	407	339	405	412	346	394	413	351	391	404
Flash point, TCC, F			105			96			107			102
Freezing point, F			—59			—117			—92			—94
Paraffins, volume per cent	89.0	81.5	68.4	61.8	57.5	24.2	76.2	69.2	32.5	73.4	61.8	39.3
Olefins, volume per cent	0.6	0.7	1.0	0.2	0.3	0.5	0.8	1.1	2.1	0.3	0.4	1.3
Naphthenes, volume per cent	9.3	15.5	26.6	36.7	39.5	70.8	18.5	24.3	54.5	25.2	36.2	55.2
Aromatics, volume per cent	1.1	2.3	4.0	1.3	2.7	4.5	4.5	5.4	10.9	1.1	1.6	4.2
Aniline point, F	148	150	156	139	140	143	136	136	137	143	143	148
Refractive index at 68 F	1.3979	1.4054	1.4239	1.3990	1.4066	1.4313	1.4000	1.4040	1.4331	1.4024	1.4118	1.4322
Total sulfur, weight per cent	0.044	0.041	0.036	0.020	0.025	0.041	0.008	0.010	0.016	0.021	0.028	0.048
Mercaptan sulfur, weight per cent	0.005	0.006	0.008	0.005	0.005	0.004	0.001	0.002	0.002	0.001	0.002	0.005
Doctor test	sour	sour	sour	sour	sour	sour	sour	sour	sour	sour	sour	sour
Copper strip Cor. 3 hr at 122 F	2	1	0	4	4	3	0	0	0	3	4	4
Research octane number												
Clear	10.5	4.2	<0	58.2	49.8	31.7	56.4	49.0	23.6	45.6	40.2	19.6
+ 1 ml. TEL per gallon	22.2	11.4		67.1	62.0		68.4	62.3		60.0	51.7	
+ 3 ml. TEL per gallon	42.0	33.5		78.1	73.2		78.7	73.0		72.0	66.0	

TABLE 7. Inspection data on distillate fractions from Oklahoma crude oils.

Crude oil source	Burbank		West Edmond		Elk City		Golden Trend Composite	
Fraction	Kerosene	Diesel fuel	Kerosene	Diesel fuel	Kerosene	Diesel fuel	Kerosene	Diesel fuel
Boiling range, F	330—525	400—650	330—525	400—650	330—525	400—650	330—525	400—650
Yield, volume per cent of crude	21.6	28.7	22.9	24.7	19.8	20.8	21.6	24.0
Gravity, API at 60 F	43.4	38.1	44.3	39.0	43.6	38.8	45.3	39.5
ASTM distillation, F								
Per cent first drop	347	408	361	384	352	404	344	412
5	363	445	371	450	364	440	357	446
10	373	461	379	463	373	458	364	455
30	390	488	398	491	392	479	381	475
50	414	521	422	517	415	502	399	499
70	440	561	454	548	441	535	424	530
90	474	606	489	590	478	583	457	572
95	488	622	501	605	492	600	468	587
End point	492	635	520	622	508	617	489	604
Viscosity, SUV at 100 F		36.22		35.78		34.88		35.20
Flash point, F	134 (TCC)	198 (PM)	143 TCC)	204 (PM)	136 (TCC)	188 (PM)	129 (TCC)	194 (PM)
Cloud point, F	—54	+6	—46	—8	—54	0	<—50	0
Pour point, F	—50	—5	—45	—5	<—50	—10	<—50	—15
Freezing point, F	—48		—44		—53		—62	
Paraffins, volume per cent	24.0		29.2		31.0		31.3	
Olefins, volume per cent	2.0	4.2	1.4	3.1	2.9	4.6	2.1	3.8
Naphthenes, volume per cent	64.5		58.0		51.0		56.9	
Aromatics, volume per cent	9.5	7.8	11.4	10.4	15.1	15.4	9.7	8.5
Aniline point, F	149	166	153	165	145	157	148	163
Refractive index at 68 F	1.4478	1.4620	1.4494	1.4611	1.4488	1.4618	1.4450	1.4585
Total Sulfur, weight per cent	0.037	0.14	0.015	0.06	0.022	0.05	0.028	0.08
Mercaptan Sulfur, weight per cent	<0.001		<0.001		0.002		<0.001	
Doctor Test	sweet		sweet		sour		sweet	
Copper strip corrosion, 3 hr	2 (122 F)	4 (212 F)	2 (122 F)	3 (212 F)	0 (122 F)	0 (212 F)	0 (122 F)	1 (212 F)
Conradson carbon res. weight per cent		0.06 (10% Btms)		0.06 (10% Btms)		0.01 (10% Btms)		0.04 (10% Btms)
Lamp burning test, 24 hr	passes		passes		passes		passes	
Cetane number		58.8		56.9		54.8		56.4

TABLE 8. Inspection data on distillate fractions from Kansas crude oils.

Crude oil source	Davis Ranch		Bemis-Shutts composite		Seeley Wick		West Kansas composite	
Fraction	Kerosene	Diesel fuel	Kerosene	Diesel fuel	Kerosene	Diesel fuel	Kerosene	Diesel fuel
Boiling range, F	330—525	400—650	330—525	400—650	330—525	400—650	330—525	400—650
Yield, volume per cent of crude	16.5	25.1	19.4	24.4	21.0	24.8	20.9	25.1
Gravity, API at 60 F	48.2	42.1	43.0	38.0	44.0	38.8	45.0	39.7
ASTM distillation, F								
Per cent first drop	341	419	351	400	339	405	361	402
5	366	451	354	431	357	436	368	432
10	375	461	367	443	363	447	374	445
30	398	488	391	475	383	470	392	470
50	423	514	418	502	410	494	416	497
70	448	543	449	534	433	527	443	528
90	476	575	485	576	464	568	480	568
95	485	586	497	591	477	581	495	583
End point	501	605	511	602	493	599	509	598
Viscosity, SUV at 100 F		35.07		35.23		34.72		34.94
Flash point, F	132 (TCC)	202 (PM)	125 (TCC)	168 PM)	121 (TCC)	188 (PM)	127 (TCC)	190 (PM)
Cloud point, F	—30	+4	<—50	—18	—50	—10	<—50	—12
Pour point, F	—25	+5	<—50	—30	—50	—10	<—50	—10
Freezing point, F	—27		—63		—53		—51	
Paraffins, volume per cent	53.7		10.6		25.5		21.1	
Olefins, volume per cent	1.6	3.9	1.6	3.8	3.1	5.5	1.9	3.7
Naphthenes, volume per cent	38.5		81.4		59.0		70.4	
Aromatics, volume per cent	6.2	6.1	6.4	8.2	12.4	10.5	6.6	7.8
Aniline point, F	160	169	147	158	146	151	153	163
Refractive index at 68 F	1.4383	1.4539	1.4442	1.4610	1.4442	1.4571	1.4438	1.4576
Total sulfur, weight per cent	0.055	0.16	0.067	0.12	0.023	0.07	0.061	0.18
Mercaptan sulfur, weight per cent	0.004		0.001		0.001		0.004	
Doctor test	sour		sour		sour		sour	
Copper strip corrosion, 3 hrs	2	>4 (212 F)	3	>4 (212 F)	0	1 (212 F)	4	>4 (212 F)
Conradson carbon res. weight per cent		0.02 (10% Btms)		0.02 10% Btms)		0.04 (10% Btms)		0.07 (10% Btms)
Lamp burning test, 24 hrs	passes		passes		passes		passes	
Cetane number		71.5		57.7		54.7		61.7

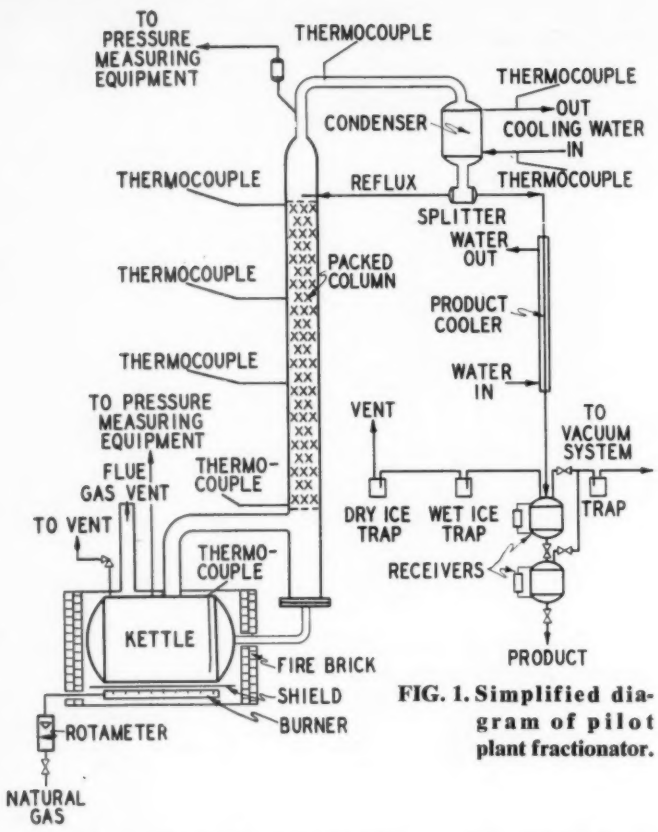


FIG. 1. Simplified diagram of pilot plant fractionator.

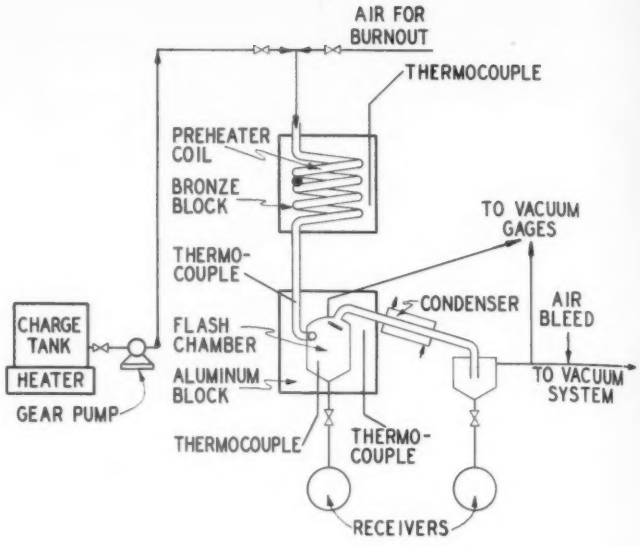


FIG. 2. Schematic diagram of vacuum flash still.

ably make end point undercutting necessary. The paraffinic Davis Ranch diesel fuel has an exceptionally high cetane number of 71.5.

The good quality of the lubricating oil fractions from the West Edmond and Burbank type crudes is well known.

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By comparison of Hempel and pilot plant lube range fractions it appears probable that all of the Oklahoma crudes tested, with the exception of the Seminole and S. E. Red Spring, would produce fair to good quality lube fractions. The Liberal light crude is the only Kansas crude oil tested that shows much possibility of good quality lube fractions. Based on the high pour point of this crude oil, however, the wax contents would almost certainly be very high.

The topped crudes from the pilot plant fractionations were vacuum flashed to separate the heavy gas oil fractions from the asphaltic residuals. Yields of vacuum residues from the various crude oils are shown as a function of the flash temperature, corrected to one atmosphere[1], in Fig. 3.

The vacuum gas oil from the Davis Ranch crude oil is unusual in that it is much less paraffinic than the gas oils from the other crude oils tested. The low gravities of the Hempel still residues of the Norton and the Jelinek crudes suggest that these crudes also have comparatively low gravity and low aniline point heavy gas oil fractions. In general the Oklahoma crude oils tested show more paraffinic gas oil cracking stocks than do the Kansas crudes.

The vacuum flash data indicate that it would be quite difficult to reduce the Oklahoma crudes to asphalt by this method. There would appear to be more prospect of obtaining asphalts from the Mt. Vernon and S. E. Red Spring crude oils as they more nearly resemble some of the Western Kansas

TABLE 9. Inspection data on light gas oil fractions from Oklahoma crude oils.

Crude oil source	Burbank	West Edmond	Elk City	Golden Trend composite
Fraction	Light gas oil	Light gas oil	Light gas oil	Light gas oil
Boiling range, F	525—650	525—650	525—650	525—650
Yield, volume per cent of crude	14.5	9.5	8.9	11.9
Gravity, API at 60 F	35.3	35.8	36.3	37.1
ASTM distillation				
Per cent first drop	528	537	521	510
5	551	559	545	529
10	558	569	549	534
30	573	582	560	543
50	586	589	570	554
70	601	598	583	568
90	624	612	606	589
95	635	620	620	599
End point	647	636	626	612
Viscosity, SUV at 100 F	42.72	42 97	40.41	40.00
Flash point, PM, F	275	285	265	260
Cloud point, F	20	16	24	4
Pour point, F	20	20	20	5
Olefins, volume per cent	7.1	4.8	7.1	6.4
Aromatics, volume per cent	7.4	7.7	12.9	7.1
Aniline point, F	175	176	169	172
Refractive index at 68 F	1.4692	1.4690	1.4691	1.4655
Total sulfur, weight per cent	0.22	0.13	0.08	0.13
Copper strip corrosion, 3 hr at 122 F	1	0	0	0

crudes that produced asphalts by vacuum flashing. The topped crude from Davis Ranch crude oil is quite asphaltic but it requires a high equivalent flash temperature to approach 100 penetration asphalt residue.

Equipment

Hempel Distillation. Laboratory crude oil analyses are made with the familiar Bureau of Mines Hempel apparatus.

Pilot Plant Fractionation. The pilot plant batch fractionator consists of a kettle, packed column, condenser, reflux splitter, receivers, and auxiliary equipment. The 80-gal gas-fired kettle is mounted in a fire-box over a natural gas burner and is shielded from the flame by a metal plate. The 6-in. diameter column is packed with 8 ft of ½-in. Berl saddles. Four electrical heaters are situated along the length of the column to prevent heat losses. Overhead vapors are condensed in a water-cooled, shell and tube condenser and the distillate is separated by a splitter into equal volumes of reflux and product. Reflux is returned to the column through a distributor located just above the packing. The product is collected in 2-gal receivers. Other equipment includes wet and dry ice traps on the vent lines, a vacuum surge tank, a mechanical vacuum pump, a temperature indicator, and pressure measuring equipment. A simplified diagram of the fractionator is shown in Fig. 1.

Pilot Plant Flash Still. The pilot plant continuous vacuum flash still comprises a preheater, flash chamber, condenser, receivers, and auxiliary equipment. The preheater is a 13-ft length of ½-in. stainless steel tubing wound in a 6-in. diameter coil. The coil is cast in an electrically heated bronze block. The flash chamber is a 6-in. diameter by 10-in. long vessel cast in an electrically heated aluminum block. The chamber has a tangential feed entry and an entrainment baffle at the vapor exit. The condenser is a pipe jacketed for either cooling water or steam. Thick-walled glass receivers are used to collect overhead and bottoms products. Thermocouples are located in the preheater block, flash chamber, and the flash chamber block. Auxiliary equipment consists of an electrically heated charge vessel, a gear-type charge pump, a mechanical vacuum pump, a temperature indicator, temperature controllers, and McLeod-type and aneroid-type vacuum gages. Fig. 2 is a schematic diagram of the vacuum flash still.

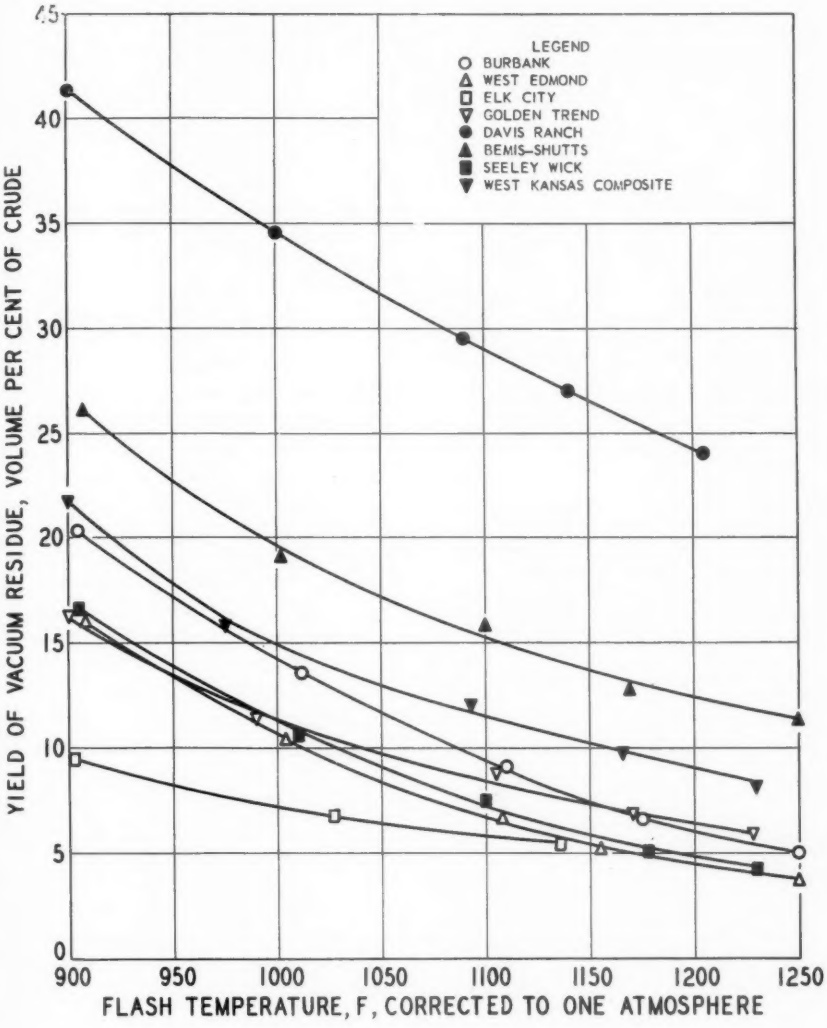

FIG. 3. Flash curves for Oklahoma and Kansas crude oils.

TABLE 10. Inspection data on light gas oil fractions from Kansas crude oils.

Crude oil source	Davis Ranch	Bemis-Shutts composite	Seeley Wick	West Kansas composite
Fraction	Light gas oil	Light gas oil	Light gas oil	Light gas oil
Boiling range, F	525—650	525—650	525—650	525—650
Yield, volume per cent of crude	13.7	11.5	11.4	11.7
Gravity, API at 60 F	39.4	35.1	35.7	37.0
ASTM distillation, F				
Per cent first drop	514	481	515	497
5	535	528	531	522
10	541	535	536	529
30	552	548	548	541
50	564	559	556	551
70	575	568	567	563
90	592	590	586	581
95	600	599	597	592
End point	610	609	609	607
Viscosity, SUV at 100 F	38.71	40.48	39.74	39.48
Flash point, PM, F	270	250	265	260
Cloud point, F	18	12	12	10
Pour point, F	25	5	15	15
Olefins, volume per cent	5.6	4.9	8.3	5.8
Aromatics, volume per cent	5.4	9.4	8.7	8.2
Aniline point, F	175	167	167	172
Refractive index at 68 F	1.4611	1.4690	1.4665	1.4657
Total Sulfur, weight per cent	0.24	0.16	0.13	0.30
Copper strip corrosion, 3 hrs at 122 F	0	0	0	1

Procedure

All crude oils evaluated are first characterized by the Bureau of Mines Hempel distillation. Samples that require a more detailed analysis are further processed by pilot plant fractionation and subsequent vacuum flashing of the fractionator residuum.

In the pilot plant tests a weighed sample of crude oil is charged to the pilot plant batch fractionator. The column is operated at total reflux until good vapor-liquid contact is obtained and then the operation is changed to a reflux ratio of one. The fractionation is performed at atmospheric pressure until the kettle temperature reaches 600 F. Remainder of the fractionation is at an absolute pressure of 5 to 10 mm of mercury. Distillate products are collected, weighed, and sampled for inspection tests. Cut temperatures (corrected to a pressure of one atmosphere)

TABLE 11. Inspection data on vacuum flash products from Oklahoma crude oils.

Crude oil source	Burbank		West Edmond		Elk City		Golden Trend composite	
Operating conditions								
Pressure, mm mercury absolute	1.5	1.0	2.0	1.0	2.0	0.7	2.0	1.1
Temperature, F	578	686	586	669	606	642	574	684
Temperature, F corrected to 1 atmosphere (1)	1012	1175	1004	1155	1027	1136	990	1170
Vacuum gas oil								
Boiling range	650—1012	650—1175	650—1004	650—1155	650—1027	650—1136	650—990	650—1170
Yield, volume per cent of crude	25.3	32.1	23.9	29.1	14.3	15.6	24.6	29.2
Gravity, API at 60 F	27.5	25.9	28.8	27.7	28.6	28.0	28.1	27.0
Vacuum Distillation, F*								
Per cent first drop	690	700	659	690	670	715	660	670
5	718	725	694	709	701	722	685	692
10	732	738	715	724	709	732	705	711
30	770	797	757	780	751	782	760	772
50	830	870	803	854	816	828	820	850
70	890	981	886	950	885	915	883	940
90	970	Cracked	988	1080	995	1010	970	1085
Aniline point, F	208	216	208	212	203	204	203	207
Viscosity, SUV at 100 F	274.2		201.5	292.1	198.8	285.2	219.4	413.5
Viscosity, SUV at 210 F	48.98	56.75	46.36	52.36	45.31	47.30	45.98	53.12
Pour point, F	90	100	90	95	85	90	70	85
Total sulfur, weight per cent	0.38	0.40	0.26	0.28	0.18		0.27	0.30
Conradson carbon res. weight per cent	0.09	0.62	0.11	0.45	0.15	0.28	0.11	0.36
Ash, weight per cent	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Vacuum residue								
Yield, volume per cent of crude	13.6	6.7	10.4	5.2	6.8	5.5	11.5	7.0
Gravity, API at 60 F	20.6	17.7	21.1	19.8	23.2	22.8	20.2	19.3
Viscosity, SFV at 122 F	668	1503	1217	1722	120.2	135.4	966.4	1532
Viscosity, SFV at 210 F	43.2	97.5	35.7					
Total sulfur, weight per cent	0.62	0.68	0.41	0.48	0.41		0.59	0.73
Conradson carbon res. weight per cent	7.67	12.38	4.66	7.65	3.73	4.62	5.34	7.01
Ash, weight per cent	<0.01	0.03	<0.01	<0.01	0.03		0.03	0.08
Penetration, mm per 10, 100 g per 5 Sec per 77 F	>260	>260	>260	>260	>260	>260	>260	>260

* Phillips Petroleum Company procedure.

TABLE 12. Inspection data on vacuum flash products from Kansas crude oils.

Crude oil source	Davis Ranch		Bemis-Shutts composite		Seeley Wick		West Kansas composite	
Operating conditions								
Pressure, mm mercury absolute	2.0	1.2	2.0	1.0	2.0	1.0	3.0	1.0
Temperature, F	583	713	584	629	592	686	581	625
Temperature, F corrected to 1 atmosphere (1)	1000	1205	1002	1100	1010	1178	975	1093
Vacuum gas oil								
Boiling range	650—1000	650—1205	650—1002	650—1100	650—1010	650—1178	650—975	650—1093
Yield, volume per cent of crude	23.4	33.9	28.5	31.9	27.3	32.7	28.0	31.5
Gravity, API at 60 F	26.3	23.7	26.1	25.4	27.0	26.0	27.2	26.1
Vacuum distillation, F*								
Per cent first drop	668	680	665	665	630	635	655	662
5	684	703	684	693	662	665	675	680
10	698	722	700	711	680	684	695	696
30	752	792	752	768	740	750	754	762
50	806	877	812	837	802	830	807	837
70	865	960	886	925	872	925	877	924
90	940	1070	992	1050	980	1015	985	1052
Aniline point, F	176	176	194	195	195	202	195	196
Viscosity, SUV at 100 F	149.3	320.2	240.1	367.3	—	—	191.6	274.2
Viscosity, SUV at 210 F	43.31	53.05	47.43	51.26	46.53	52.60	45.12	49.11
Pour point, F	60	70	65	85	90	95	80	80
Total sulfur, weight per cent	0.39	0.56	0.68	0.73	0.41	0.43	0.57	0.59
Conradson carbon res. weight per cent	0.18	0.75	0.16	0.33	0.24	0.74	0.15	0.32
Ash, weight per cent	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Vacuum residue								
Yield, volume per cent of crude	34.6	24.1	19.1	15.9	10.6	5.1	15.9	12.2
Gravity, API at 60 F	9.9	6.3	10.8	9.4	17.6	12.7	10.8	8.3
Viscosity, SFV at 122 F					1472			
Viscosity, SFV at 210 F	299.0	3160	1943	>4000	63.2	285.6	665.1	4543
Total sulfur, weight per cent	0.76	0.87	1.20	1.22	0.60	0.75	1.13	1.29
Conradson carbon res. weight per cent	22.40	29.34	21.30	23.68	11.19	17.70	18.39	21.51
Ash, weight per cent	0.02	0.04	0.09	0.13	0.04	0.09	0.05	0.09
Penetration, mm per 10, 100 g per 5 sec per 77 F	>260	125	>260	98	>260	>260	>260	52
Softening point, ring and ball, F		117		118				135
Ductility, cm, 5 cm per min per 77 F		132		>150				139
Loss on heating, weight per cent		0.05		<0.01				0.01
Spot test, naphtha, 24 hrs		negative		negative				Negative
Solubility in CCl_4, weight per cent		99.82		99.91				99.93
Solubility in CS_2, weight per cent		99.88		99.86				100.00

* Phillips Petroleum Company procedure.

are 330 F, 400 F, 525 F, and 650 F.

This break-up of the crude and blends of the various fractions produces 2 gasolines (IBP-330 and IBP-400 F), a jet fuel (IBP-525 F), a naphtha (330-400 F), 2 kerosines (330-525 and 400-525 F), a diesel fuel (400-650 F), and residuum (650 F and heavier). After draining the 650 F and heavier residuum from the kettle a weighed amount of butane-free gasoline is charged to the still and refluxed. The amount of 650 F and heavier material left in the still after the crude oil fractionation is calculated from an ASTM distillation of the resulting kettle product. Additional charges of the gasoline are required to clean the still for subsequent fractionations.

The 650 F and heavier residuum from the batch fractionation is vacuum flashed at several sets of temperatures and pressures to produce vacuum gas oils and vacuum residues. Flashing conditions usually range from 900 F (corrected to a pressure of 1 atmosphere) to the most severe conditions attainable without appreciable cracking. Minimum flash still pressures are 0.7 mm of mercury absolute. The 650 F and heavier charge material is pumped to the preheater at a rate of about 0.5 gal per hour. After sufficient amounts of products are produced the flow of feed is stopped and the overhead and bottoms products are allowed to drain for 30 minutes. The products from each flash condition are then weighed and samples retained for inspection tests. Upon completion of a series of tests air is introduced to the still to burn carbon from the preheater coil and flash chamber. This is followed by a kerosine flush of the entire system.

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Polymerization, alkylation, dehydrogenation are major processes for making

Derivative Hydrocarbons

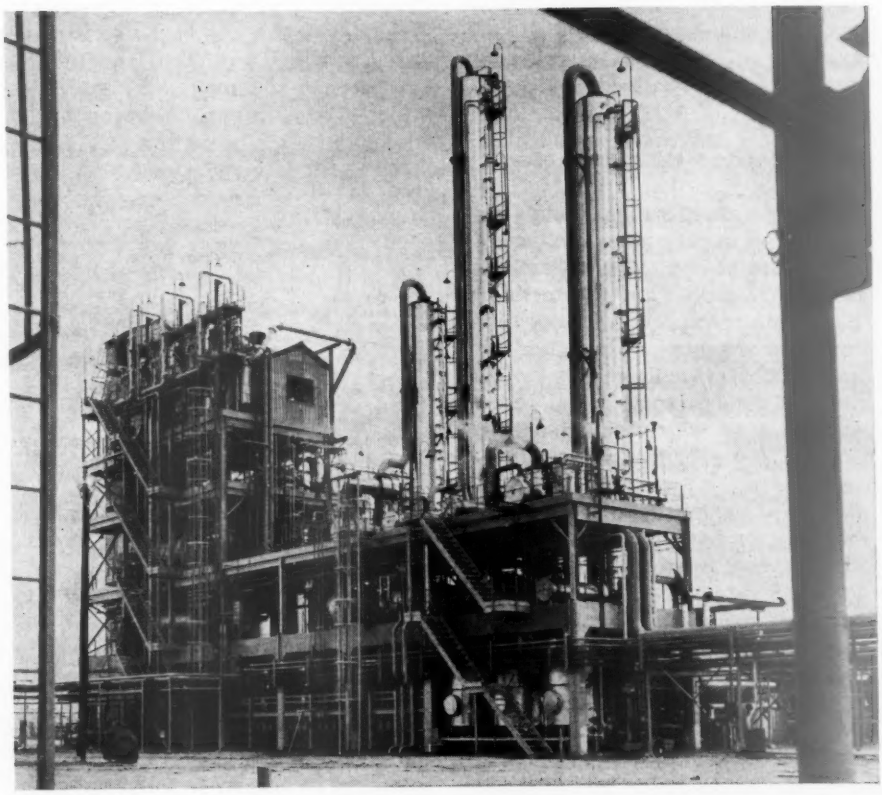
Peter W. Sherwood*

THE route to many petrochemical products of the lower aliphatics leads via derivative hydrocarbons. Three types of unit processes for their synthesis acount for almost the entire activity in this field.

(a) Polymerization of monoolefins;
(b) Alkylation,
(c) Dehydrogenation.

As applied to the field under consideration, all three processes have had a relatively short commercial history. None antedated World War II—except for some operations on a very limited scale. Today all are major consumers of lower aliphatic hydrocarbons. Alkylation accounted for nearly 12 per cent of U. S. ethylene output in 1953; the share of polyethylene production was some 7 per cent. Butadiene, produced by dehydrogenation, is by far the principal derivative of recovered butanes and butenes.

Some of the derivative hydrocarbons (polyethylene, polyisobutylene) are chemical end products; others (butadiene, ethyl benzene, styrene) must, in their own turn be converted to derivative hydrocarbons, while still others (cumene, dodecyl benzene) serve as raw material for wholly different types of chemical synthesis. Of necessity, the production of derivative hydrocarbons forms an important chapter in this account of the petrochemical horizons for ethane, propane, and the butanes.



Courtesy: The Koppers Company

FIG. 1. Synthesis of styrene begins in this ethylbenzene plant at a Port Arthur, Texas, plant.

Polymerization Process Products

Production of Nonene and Dodecylene. Petrochemical importance attaches to the production of nonene and dodecene by polymerization of propylene. Nonene, the trimer of propylene, serves in the production of nonyl phenols. The more important tetramer of propylene—dodecylene—is reacted with benzene to yield dodecyl benzene. Both of these intermediates find their eventual principal end use in the manufacture of synthetic detergents.

Polymerization of C_3—C_4 olefins to products in the gasoline boiling point range is widely practiced today in refining installations. Numerous polymerization processes have attained commercial stature. They may be classified into the following categories:

1. Thermal polymerization
2. Catalytic polymerization
   (a) Phosphoric acid catalyst
   (b) Hot sulfuric acid process
   (c) Cold sulfuric acid process

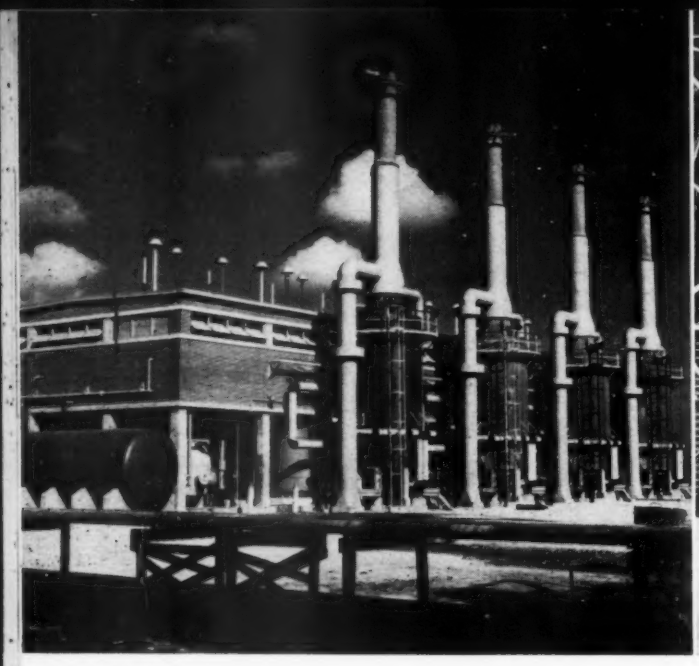
All lead to products of predominantly (90 per cent +) olefinic character.

For the polymerization of propylene (alone), phosphoric acid-based processes are used par excellence. The leading process, developed by Universal Oil Products Company, uses a solid catalyst of phosphoric acid on a kieselguhr carrier. The material is provided in ¼ by ¼ in. pellets and is arranged in a fixed-bed reactor.

Three types of converter are used in phosphoric acid - catalyzed polymerization. The oldest type is a catalyst-packed tower operated slightly below the stabilizer pressure of the cracking plant where the feed olefins are derived. Because of rapid catalyst fouling at the relatively low pressure, regeneration is necessary. This is accomplished by burning, whereby a low oxygen concentration must be maintained to prevent overheating. After regeneration, steam is turned into the converter in

*Chemical engineer

EXCLUSIVE



Courtesy: Dow Chemical Company

FIG. 2. One of four ethyl-benzene cracking units of Dow Chemical Company's Velasco, Texas plant, making styrene.

FIG. 3. Battery of fractionators for purification of raw styrene as produced in units shown in Fig. 2.

order to rehydrate the catalyst to maximum activity.

Because of rapid catalyst fouling and high cost of regeneration equipment, low-pressure (250 psi) polymerization has come into disfavor. By operating a catalyst tower at 500 psi, min, sufficiently low operating temperature becomes feasible to cut down very considerably on catalyst fouling and regeneration may be wholly eliminated. At the same time, better conversion is attained.

The most modern type of polymerization reactor is of the shell-and-tube design. It, too, is operated at elevated pressure. Substantially isothermal conditions are maintained, while heat of polymerization (670 Btu per propylene) causes a temperature rise of about 40 C between inlet and outlet of adiabatic catalyst towers. The close temperature control, which is possible in isothermal (shell-and-tube) converters, boosts catalyst life, olefin conversion, and polymer yield. Regeneration is not necessary.

Feed to the phosphoric acid catalyst must be pretreated for removal of sulfur and nitrogen compounds, as well as of oxygen, butadiene, and excess water. A small amount of moisture must be present in order to prevent loss of catalyst activity by dehydration.

Typical of operation in the three types of polymerization converters are the conditions reported by Weimert and Egloff for processing C_3 - C_4 mixtures. (*See table above.*)[1]

Polymerization processes in refinery practice lead to a complex hydrocarbon mixture, predominating in the C_6-C_9 range. For the preferential production of one specific compound (propylene tetramer), steps must be taken to achieve substantial improvements in its yield over that obtained in normal practice.

TABLE 1.

	Tower type		Shell and tube
	Low-pressure regeneration	High-pressure	
Pressure, psi	250	500	900
Catalyst temp., °C			
Inlet	203	190	203
Outlet	245	232	212
Olefin Content,%			
Fresh feed	35	35	35
Combined feed	20	20	35
Spent gas	10	5–7	4
Olefin conversion,%	80	85–90	92
Catalyst life, gal/lb catalyst	50	75	150

This objective may be attained by recycling the lighter-boiling by-products to the reaction stage after separation from the desired tetramer. In a process developed by Universal Oil Products Company,[2] yields of the order of 75 per cent of theory are achieved by this mode of operation.

The catalyst is a pre-calcined mixture of pyrophosphoric acid and kieselguhr.[3] Conditions are chosen to maintain a mixed liquid-and-vapor-base within the reactor. In the vapor phase, the main components are unconverted proplyene plus recycle propylene dimer and some trimer, while most of the trimer plus, of course, higher-boiling products, are present as liquids. The converter effluent is cooled and condensed (propylene itself remains in gas phase). After separation from the tetramer, the dimer and trimer of propylene are recycled to the converter where they are joined by make-up proplyene. (If nonene is also a desired product, only the dimer is recirculated.)

A fairly dilute proplyene stream may serve as feedstock. The reaction for tetramer production is carried out in the operating range outlined above for non-specific polymerization. Mayland et al.[2] cite an example in which the feed stock is 31 per cent proplyene, 65 per cent propane, 2.5 per cent butenes, and 1.5 per cent higher hydrocarbons, 0.5 wt per cent moisture is added to the charge (to safeguard the catalyst). The stream is fed to the reactor containing UOP phosphoric acid catalyst. Conversion is carried out at 230 C and 900 psi inlet pressure. The gaseous reactor make enters a partial dephlegmator, mainly for condensation of propylene dimer. The liquid so formed is recovered and returned to reactor feed tanks for repolymerization.

Product leaving the reactor in the liquid phase is fractionated. Overhead trimer may be sold as nonene product or it may be returned to the polymerization reactor for further upgrading to the tetramer.

The bottoms of the primary fractionation column are further distilled for the recovery of tetramer from associated higher hydrocarbons. In operation for maximum tetramer yield (i. e. with complete trimer recycle) about 75 per cent of the feed propylene is accounted for as the desired product.

A further improvement in yield is claimed[4] if only the C_8-C_{10} product (i. e. chiefly propylene trimer) is recycled to primary reactor. The lighter condensible fraction (chiefly propylene dimer) is polymerized separately.

As may be expected, none of these polymerization reactions lead solely to the self-condensation derivatives of propylene. The various fractions also contain by-products arising from numerous side reactions, and a bleed stream of dimer and trimer recycle must be taken in order to prevent undue build-

up of the waste material contained therein.

Polyethylene. Polyethylene plastics are the giant newcomers among consumers of ethylene. The product was first introduced in 1943. By 1952, output had passed the 100,000,000 lb per-year mark. Production in 1953 estimated at 140,000,000 lb accounted for 7 per cent of all ethylene consumed during that year.

The field of polyethylene production is characterized by unusually vivid activity. In mid-1954, only two American companies (DuPont and Bakelite) were engaged in its manufacture. Other companies are getting into this field and, at present outlook, ten firms should be actively producing polyethylene by mid-1955. Total plant capacity should be between 500,000,000 and 600,000,000 lb per year by then.

Polyethylene consumption pattern has shifted markedly from early emphasis on electrical insulation to today's predominance of film for packaging purposes, a trend that is likely to continue. During 1953, polyethylene consumption is estimated to have had the following distribution pattern: Film-30 per cent; Wire- and cable - 25 per cent; Pipe - 15 per cent; Injection molding products - 13 per cent; Papers and coating - 1 per cent and bottles - 6 per cent.

Polyethylene production is still a relatively virgin field with outstanding growth outlook. Most conservative view is taken by the Paley Commission report[5] which looks to a 1960 production of only 500,000,000 lb (one billion lb in 1975). Kuhn and Hutcheson's careful study[6] made in 1951, forecasts 1960 sales at 700,000,000 lb. Current view is even more optimistic, and it is expected that polyethylene production in 1960 will be just short of a billion lb.

In this connection, the term "polyethylene" is used to denote ethylene polymers with an average molecular weight in excess of 15,000. These materials exhibit the valuable physical properties (toughness, good electrical properties, good flexibility, translucency, etc.) by which they have captured so impressive a market in the plastics field. Polyethylene in this category is produced at very high pressures (above 1000 atmospheres) by methods that will be outlined below.

It must be recognized, however, that ethylene may also be polymerized to products of lower molecular weight—and entirely different characteristics—by the use of wholly different techniques. Synthetic lube oils and waxes have been produced in this fashion, but the field has not proved very fruitful.

Present manufacturing methods for polyethylene plastics are based on the original work of Imperial Chemical Industries[7], which disclosed a process for polymerization of ethylene at pressures above 1000 atmospheres, at temperatures of 100 to 200 C with quick removal of heat, and in the presence of oxygen not exceeding a definite small percentage (order of 0.1 weight per cent). The molecular weight of the polymer was found to be in direct relation to the pressure and inversely related to oxygen (catalyst) content.

Polymerization of ethylene is accompanied by the evolution of unusually large heat reaction (1440 Btu per lb). Its dissipation constitutes a severe engineering problem. The conversion is carried out in indirectly cooled, thick-welled tubes of small inside diameter. Units of this design initially gave much difficulty as they were recurringly plugged by cross-linked polymer. A better understanding of the reaction principles has led to minimization of this difficulty. Of particular importance in this connection is proper control of oxygen concentration, and a minimum inside diameter of 0.4 in. in the reactor tubes.

For the production of solid polyethylene, polymerization is carried out in homogeneous dense (gas) phase in the presence of oxygen, which serves as catalyst. The feed ethylene must be of outstanding purity.

In the presence of catalyst, high initial reaction rates are obtained and a conversion of 5 to 20 per cent of the ethylene may be attained in a few seconds. The catalyst itself is consumed in the course of reaction whereby the conversion rate is reduced to unfeasibly low values. Initial oxygen concentration, on the other hand, is limited by its depressive effect on molecular weight of the polymer, and by the occurrence of explosive decomposition (above approximately 0.16 per cent). As a result, it is necessary to operate the reaction at low conversion per pass. Ethylene in the tail gas is purified and recycled.

Even inert impurities are objectionable since a small concentration in the feed gas rapidly depresses ethylene partial pressure in a recycling operation of this type. Ethylene specification in U. S. plants is generally 99 per cent, but concentrations as low as 98 per cent may be technically feasible.

A commercial process for the production of polyethylene has been piloted at Ludwigshafen.[8] Here, the feed gas assayed 98 per cent ethylene, 0.5-1.0 per cent nitrogen, 0.1-0.3 per cent acetylene, the balance ethane. The reaction was carried out in 15-ft tubes with an internal diameter of 0.4 in. Individual tubes were vertically arranged and a wax separator provided at each lower elbow in order to minimize clogging. Cooling is provided by circulating water through jackets surrounding each tube.

In polymerization at 1000 atmospheres, the reaction is carried out in two stages. Initial conversion is effected at 180 to 190 C, and the final polymerization takes place at 90 to 100 C. The ethylene feed has an oxygen content of 0.05 to 0.1 per cent at the reactor entrance.

Pressure may be released in one or two stages. In the former case, the system is cooled sufficiently (due to expansion) to cause precipitation of solidified polyethylene as a fine powder. Alternately, the first pressure reduction is taken to 200 atmospheres, whereby most of the polymer pressure is deposited as a liquid. The final reduction to atmospheric pressure yields a small amount of polyethylene of low molecular weight. An important advantage of two-stage pressure release is the elimination of this lower grade material from the main product.

Unconverted ethylene is washed with caustic solution. Here, the small amounts of aldehydes and oil-type products are removed. At the same time, the ethylene picks up the requisite amount of make-up oxygen before it is recycled to the converters.

The Ludwigshafen pilot plant yielded a product with a molecular weight of 15,000 to 20,000 (at 1000 atmospheres). Conversion is reported at 84 to 15 per cent, and effective yield, based on ethylene, is 93 to 96 per cent.

An alternate process, operated at Zweckel for the production of polyethylene waxes, involved polymerization in the presence of methanol solvent and benzoyl peroxide, together with oxygen, as catalyst. Conversion is effected at 200 atmospheres and 115 to 120 C. The polymer is a specialty product of limited commercial interest.

Polyisobutene. Polymerization of isobutylene falls properly within the scope of the plastics and rubber industries. Only a brief outline of methods need then be given in this discussion.

Isobutlylene has a much more pronounced polymerization tendency than either ethylene or propylene. Indeed, the reaction is carried out at very low temperatures and substantially atmospheric pressure. Heat evolution is moderate (412 Btu per lb) but, at the low polymerization temperatures, it imposes a severe burden on the refrigeration system.

Blouri[9] distinguishes the following techniques applicable to isobutylene polymerization:

A. Homogenous systems
   (a) Mass polymerization (i.e. in the absence of diluent)
   (b) Polymerization in solution

B. Hetergenous systems
(a) Emulsion polymerization
(b) Suspension polymerization

In mass polymerization, which is carried out in the absence of a diluent, temperature control is extremely difficult to achieve and, indeed a non-uniform product is obtained.

Drawback of using a solvent is the strongly depressive effect on reaction rate and the difficulty—if not complete impossibilty — of separating residual solvent entirely from the product. Nevertheless, this method figures prominently in isobutylene polymerization. Among the solvents of interests are methyl chloride, ethyl chloride, ethane, propane, and liquid nitrous oxide (N_2O). Catalysts of Friedel-Crafts type ($AlCl_3$, BF_3) are used and temperature is between —90 and —70 C.

Polymerization in a *heterogenous system* is effected in a medium in which neither the monomer nor the polymer is soluble. Methods in this category permit ready removal of heat and can lead to products of high purity and uniformity. Emulsion polymerization is achieved by the addition of an emulsifying agent to the system. The product polymer is of extremely fine particle size and is of the nature of a latex. Suspension polymerization leads to the formation of beads (1-5 mm diameter) and is brought about in the presence of only a small amount of emulsifying agent (or, at low monomer:dispersant medium ratios, none at all). In either case, agitation is provided, and a catalyst is employed. For isobutylene polymerization, useful catalysts include $AlCl_3$, BF_3, and some peroxides.

The molecular weight of polymer may be raised by operating at low temperatures. This factor precludes the use of water as dispersing agent in the production of an acceptably isobutylene polymer. The suspension agent should have the following characteristics: (a) Freezing point below —70 C: (b) Inertness to the polymerization catalyst; (c) Immisicibility with the monomer at the operating temperatures. These demands are satisfied by certain flourinated hydrocarbons, such as perfluoro-m-xylene.

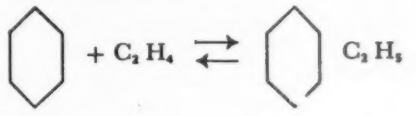
Isobutylene may be polymerized by itself, or it may be copolymerized with other monomers (isoprene, indene, butadiene, etc.) to yield polymers of widely ranging properties.

Products of Alkylation Processes

Ethyl Benzene. Ethylbenzene, the largest single outlet for benzene, is also a major consumer of ethylene. America's 1953 output of 940,000,000 lb accounted for the consumption of 256,000,000 lb ethylene, 12 per cent of the total output.

Almost all ethylbenzene produced serves as intermediate in styrene synthesis. Only a minor amount is diverted to other derivatives, among which acetophenone figures prominently.

Equation (1) symbolizes the synthesis of ethylbenzene.



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The reaction is most commonly carried out in the liquid phase in the presence of aluminum chloride. An alternative approach involves high-pressure alkylation over silica-alumina of phosphoric acid-based catalysts. The latter method avoids corrosive potential and the cost of aluminum chloride replacement. Its disadvantages include, however, not only the inherently higher cost of high-pressure plants, but also the unsuitability of the vapor-phase process for equilibration, i. e. the conversion of polyethylbenzene to ethyl benzene which will be discussed below.

Commercial processes for benzene ethylation in the liquid phase were developed in the United States by Dow Chemical Company, Monsanto Chemical Company, and Carbon and Carbide Chemicals Company, working independently at first. Quite similar processes were arrived at by the various investigators except that Carbide's alkylation calls for the use of slightly elevated pressures.

The reaction is carried out in continuous flow. The liquid medium is the mixture of benzene and its various alkylation products through which the catalyst (aluminum chloride-hydrocarbon complex) is dispersed. In order to operate at highest catalyst efficiency, the presence of a small amount of hydrogen chloride is required. This promoter may be added as such or, more commonly, in the form of ethyl chloride.

The purity of ethylene to this process is not too critical, as long as acetylene, higher olefins, and sulfur compounds are substantially absent. To achieve maximum throughput per unit converter space, ethylene concentration above 94 per cent is desirable, but lower concentrations can be used.

In order to supress polyethylbenzene formation, the use of a high benzene: Ethylene feed ratio is indicated. Since most of the polyalkylated material is recycled to the converter, the ratio is set by total number of benzene and ethylene groups introduced into system.

The optimum operating ratio of ethyl groups to benzene rings has been found to be in the range 0.55 to 0.65. This is the ratio selected for commercial operation. A typical reactor feed is thus made up of 1000-weight parts benzene, 250 parts polyethyl benzene, and 160 parts ethylene.

In American practice, the converter is a vertical cylindrical tower, lined with acid brick. Liquid height in the unit is maintained at 30 to 35 ft. All of the reactants are introduced to the bottom of the reactor, while aluminum chloride is fed through the top via a pipe that dips below liquid level.

The system is operated slightly above atmospheric pressure and at temperatures between 90 to 100 C. A considerable portion of the exothermic heat of reaction can be removed by refluxing in overhead heat exchangers.

The reaction product is withdrawn at the top of the reactor. Suspended catalyst complex is carried along with this stream and is separated from it in a settling box. Most of the catalyst so separated is returned to the converter. A small bleedstream is withdrawn from the system and may be discarded or forwarded to the high-temperature dealkylation stage operated for partial recovery of useful product from the heaviest alkylate fractions.

The amount of fresh aluminum chloride added continuously or intermittenly to the top of the reactor is gaged to balance the quantity of spent material lost with the bleedstream. Required catalyst make-up is in the range of 3 per cent on the ethylbenzene produced.

In proper operation, the off-gases from the reactor will be substantially devoid of unconverted ethylene. To assure complete recovery of vaporized benzene and ethylbenzene, that may have passed through the reflux condenser, the top gas is passed through a small absorber column in which the scrubbing medium is recycle polyalkyl benzene on its way to the reactor. Finally, residual HCL is removed by water scrubbing, sometimes preceded by a caustic wash.

The liquid main product stream contains approximately 40 per cent benzene and a like amount of ethylbenzene. The balance is principally composed of polyalkyl benzenes. Before this mixture is subjected to fractionation, it must be carefully freed of contained acid by caustic washing.

Overall benzene efficiency of liquid-phase alkylation is in the range of 94 to 96 per cent of theory. Ethylbenzene yield, based on ethylene, is in the same range and has, indeed, been reported as high as 96 to 97 per cent.

Vapor-phase ethylation of benzene finds more limited commercial application than the aluminum chloride-catalyzed liquid-phase process. It calls for elevated pressures (600 to 900 psi) and higher operating temperatures (325 C). The principal catalysts useful for vapor-phase alkylation are typified

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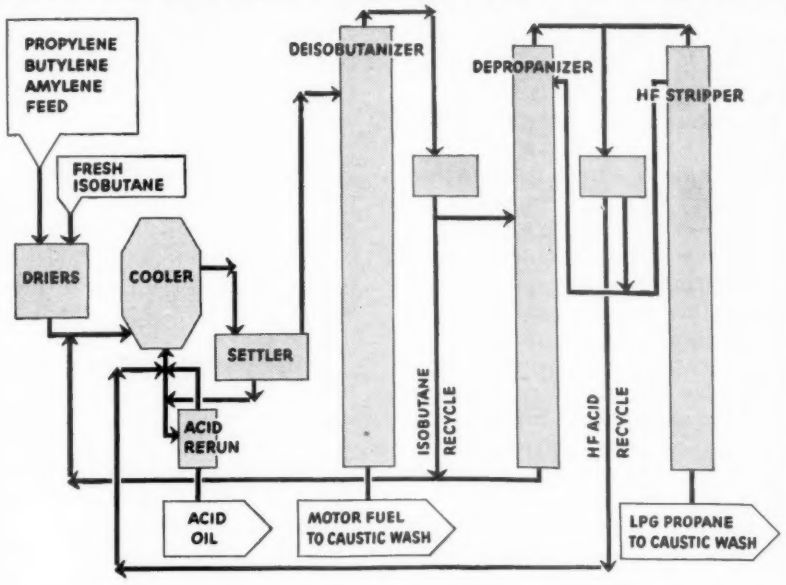

Liquid feed, containing olefins and isobutane, is passed through driers and fed into a cooler along with liquid recycle hydrofluoric acid. Hydrocarbons and recycle acid then flow to the settler. The acid phase is recycled to the cooler. The hydrocarbon phase is fractionated to separate high octane motor fuel alkylate from recycle isobutane.

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by the system alumina-silica and by phosphoric acid on suitable carriers. Conversion is carried out in fixed-bed shell-and-tube reactors.

Of importance is a process developed by Universal Oil Company[10] by which ethylene is reacted with benzene in the presence of phosphoric acid on kieselguhr. In this reaction, 80 per cent conversion of ethylene can be attained in a single-pass operation at 325 C and 600 psi (and at a benzene LHSV of 2.0). At the same temperature and benzene throughput, a boost in pressure to 900 psi will raise the ethylene conversion to nearly 95 per cent. The use of the higher pressure has the disadvantage of increasing cost of reactor construction and power requirements for ethylene compression. Advantages include greater throughput at a given temperature or, alternately, reduction in temperature with consequent increase in catalyst life.

At reaction conditions, the phosphoric acid catalyst tends to be dehydrated, with ensuing loss in activity. This phenomenon may be counteracted by the introduction of a small quantity of ethanol or water, together with the feedstock.

In the vapor-phase process, also, the benezene: ethylene ratio in the feed affects the formation of polyalkyl benzenes significantly. These high-boilers cannot be recycled to the reactor as they would tend to deposit on the catalyst and thereby destroy its activity. In order that the formation of polyalkyl benzenes may be more completely suppressed, it is therefore necessary to choose higher benzene:ethylene ratios for vapor-phase catalysis than are required in liquid-phase alkylation.

Ipatieff[12] has shown that, over UOP phosphoric acid catalyst, a benzene: ethylene mole ratio of 3:1 will result in an alkylate containing only 87 weight per cent monoethyl benzene. By boosting the ratio of reactants to 5.0, the ethylbenzene content of the (benzene-free) alkylate is raised to 93 per cent. It is evident that the use of the required high benzene:ethylene ratio imposes a severe burden on the primary (benzene distillation which is the first product purification step in any ethylbenzene process).

This objection may be alleviated somewhat by multi-stage operation. In this version of the process, only a portion of the total ethylene is fed to the primary reactor, while the balance is added to the benzene-alkylate mixture on its way to succeeding stages. Such a system will maintain a high benzene: ethylene ratio at any point in the reactors, while the overall feed ratio is kept low.

This approach is made possible by the sluggishness of the dealkylation reaction which prevents establishment of true equilibrium with polyalkyl benzenes in the course of passage through the reactor. Thus, Mattox[13] obtained, for a benzene:ethylene ratio of 6.0, an alkylate containing 96 wt per cent monoethyl benzene by executing the reaction in four stages. At otherwise the same conditions, alkylate obtained in single-stage processing contained only 85 per cent of desired product.

Ethylbenzene recovery and purification schemes for either liquid- or vapor-phase alkylation take a similar pattern, except that in processes of the latter type the load on benzene recovery equipment is greater and amount of polyalkylate fed to stills is smaller.

In substance, the product system calls for a benzene still and an ethylbenzene still in series. In addition, liquid-phase alkylation processes require a polyethyl benzene still to separate alkylate, which is suitable for recycle to the main converter, from heavy residues. Bottoms are finally processed in the high-temperature dealkylator.

The separation of benzene from ethylbenzene is straightforward, operating above all to remove benzene quite completely from the bottoms. The column is run at substantially atmospheric pressure. Benzene columns vary in height from 20 to 50 actual plates, depending on the reflux ratio selected in design. In one instance the separation is carried out satisfactorily in a 45-plate column operated with a reflux ratio of 1.0.

The overhead is dried azeotropically before it enters the feed benzene storage tanks. The bottoms have an ethylbenzene content ranging from 65 per cent (for liquid-phase) to 90 per cent (for vapor-phase alkylation). The monoalkylate product is isolated as overhead in the ethylbenzene column. Again, operation is at near-atmospheric pressure. Typical column size (liquid-phase process) calls for 57-58 plates at a reflux ratio of 3:1.

In liquid-phase alkylation plants, the bottoms from the ethylbenzene still are taken to the polyalkyl benzene column for the separation of recycle stock from the heaviest components. The operation is carried out at 25-50 mm Hg abs. The heavy fraction recovered in this operation is joined by spent $AlCl_3$-hydrocarbon complex and the mixture is treated in high-temperature dealkylation at 200 C for the partial recovery of benzene and lower alkylates.

Production of Cumene. Reaction of propylene with benzene, analogous to the ethylation process, leads to the predominant formation of cumene (i.e. isopropyl benzene). During World War II, this hydrocarbon found wide-spread use as a component of aviation gasolines. Of late, it has assumed outstanding importance to the petrochemical industries as intermediate in a newly developed process for simultaneous synthesis of acetone and phenol. The first commercial installation using this route to phenol was taken on stream in May, 1953 (by B. A. Shawinigan, Ltd.) and three more plants have since been taken into operation in the Western Hemisphere alone. Another, though less important, petrochemical derivative of cumene is alpha-methyl styrene.

As is true of ethylbenzene production, cumene may be synthesized in the liquid- or in the vapor-phase, but this is where much of the process similarity ends. Cumene production is facilitated by the greater reactivity of propylene compared to that of ethylene. Practicable conversion can therefore be achieved at medium pressures (250-400 psi) in the vapor-phase. Liquid-phase synthesis can be adequately catalyzed by sulfuric acid, thus rendering the problems of catalyst cost and handling, and of corrosion, less severe than in $AlCl_3$-catalysis.

Liquid-phase propylation of benzene found only limited application when cumene production was in its heyday during World War II, but this process was the first to be revived when petrochemical outlets were developed for cumene. The method differs from conventional sulfuric acid alkylation of paraffinic stocks principally in the use of lower acid strengths and higher operating temperatures.

Benzene and propylene feed is mixed with 88 to 90 per cent sulfuric acid in a standard water-cooled alkylation unit provided with high (20:1) internal recirculation. As practiced by the Curacaosche Petroleum Maatschapij[14], two reactors were employed in series, using split olefin feed. Benzene:propylene ratio in the charge to the two reactors is 6.2 and 5.2, respectively. Residence time in the two units is 35 and 30 minutes. Operating conditions are 165 psi (to maintain wholly liquid phase) and 35-40 C. An acid:hydrocarbon volume ratio of 1.0 is employed.

The reactor effluent is pumped to settlers where it is permitted to stratify. Most of the acid is returned to reaction phase, together with make-up acid.

The organic phase is caustic-washed. It is then depropanized in a conventional stabilizer, operated at 200 psi. The propylene-free product is fed to a low-pressure benzene recycle column. Benzene, taken overhead, is recycled to the conversion stage after azeotropic drying. The crude alkylate proper, i.e., the bottoms of the benzene recycle column, is finally fractionated in a cumene column.

Nearly complete propylene utilization is achieved in this process. Cumene content of the (benzene-free) alkylate

is about 95 per cent. Ten to 12 volumes crude alkylate are produced per volume sulfuric acid consumed.

Vapor-phase alkylation offers advantages of lesser corrosion, lower catalyst cost (per pound product) and greater operating ease. Because of these benefits and because operating pressure in vapor-phase cumene synthesis is moderate, this production method has found extensive application.

The catalyst commonly employed is a form of the orthophosphoric acid-kieselguhr composition of Universal Oil Products Company, which is also effective in benzene ethylation.

The process flow in cumene synthesis parallels closely the system employed for ethylbenzene production. Benzene (both make-up and recycle) is mixed with propylene and is fed via a heat exchanger to a fixed-bed catalytic reactor, provided with suitable cooling facilities to handle the exothermic heat of alkylation. A small amount (less than 0.1 per cent) of water (or isopropanol) must be introduced with the feedstream to prevent premature dehydration of the catalyst. Reactor make is cooled and depressurized to some 165 psi, which is operating pressure in the depropanizer column.

The heavy ends of this primary separation column enter the benzene recycle column. The alkylate recovered therein as bottoms product is finally fractionated into pure cumene product and heavy polyalkylated benzene. By-product di-isopropyl benzene may be recycled to the reactor, but the small benefit to yield, derived therefrom, is offset by reduced catalyst life and such recycling is therefore rarely practiced.

Typical operating conditions in the alkylation stage are 250 psi, 270 C, 2.5 LHSV (benzene), and a benzene:propylene ration of 5:1 to 7:1. This allows per-pass propylene conversion slightly above 90 per cent. Cumene content of the (benzene-free) alkylate is about 90 per cent.

Production of Dodecyl Benzene. Dodecyl benzene is a raw material for alkyl aryl sulfonates, the most important single group of synthetic detergents. It is obtainable by the reaction of benzene with a straight-chain C_{12}-fraction obtained either directly from a crude of the Pennsylvania or Michigan type or, more commonly, by the tetramerization of propylene which has been outlines previously. (Part II of this series, section on polymerization processes).

Today, six U. S. companies are engaged in the manufacture of dodecyl benzene. The short production history has been characterized by extremely rapid growth. The 1953 output of dodecyl benzene was 297.3 million pounds, 91 million pounds above the preceding year.

If the side chain of dodecyl benzene (or here, more properly, "keryl benzene") is obtained from paraffinic petroleum stocks, it must first be chlorinated before it may be condensed with benzene in the presence of aluminum chloride. This synthesis has been discussed by the author elsewhere.[15]

Our interest here in confined to the production of dodecyl benzene from the tetramer of propylene which, incidentally, is the second-largest petrochemical outlet for C_3-hydrocarbons. Since here the alkylating chain is of olefinic character, direct reaction with benzene is possible in the presence of aluminum chloride, hydrogen fluoride, or sulfuric acid (other catalysts are also effective but have not been employed on a commercial scale in dodecyl benzene synthesis).

The reaction system is much more complex than that encountered in benzene ethylation or isopropylation. The desired alkylation reaction must compete with fragmentation, polymerization, cyclization, and other side reactions undergone by the alkyl chain.

Where aluminum chloride is used, a minimum catalyst concentration is observed for effective execution of the reaction but only little is gained by exceeding this value beyond a reasonable margin of safety. $AlCl_3$ is effective only in the presence of hydrogen chloride which may be introduced in the usual manner (either as gaseous HCl or, less advantageously, by addition of small amount of moisture to the system.

In sulfuric acid catalysis, acid concentration of 96.5 to 100 per cent is used; strengths below 94 per cent are ineffective. Quantity of sulfuric acid is critical. As the minimum critical value is exceeded, conversion of dodecene to heavy bottoms rises steadily.

When anhydrous hydrogen fluoride is chosen as catalyst, it must be employed in large amount; a typical molar ratio of HF to feed dodecene is of the order of 4:1.

Regardless of catalyst employed, the controlling variables are operating temperature, and mole ratio of reactants. Effect of these variables has been explored by Sharrah and Feighner[16] who found that yield attains a near-asymptotic maximum value at benzene: dodecene ratios of 8-10.

As expected, the amount of heavy by-product declines with rising benzene:dodecene ratios up to this value. In aluminum chloride catalysis, bottoms product formation passes through a maximum at reactants' ratio between 3 and 4, and declines rapidly below this value. This unexpected phenomenon is believed to be caused by catalyst inactivation at high dodecylene content in the mixture. Ultimate yield may be bolstered by recycling some bottoms product to the reaction batch. Less favored, but also feasible, is the separate dealkylation of polydodecyl benzenes by reaction with benzene in the presence of aluminum chloride.

For a given reaction time, an optimum reaction temperature is observed. Aluminum chloride catalysis calls for operation at not less than 30 C; decline in yield above this optimum temperature is only very gradual. HF- and H_2SO_4-catalyzed alkylation is carried out at 0-10 C.

In practical operation, benzene:olefin ratios below optimum yield value may be made preferable by overall economic considerations. The alkylation reaction is carried out in glass-lined equipment since the presence of iron in the product has a deleterious effect on its usefulness in detergents synthesis. Adequate cooling capacity must be provided to handle the exothermic heat of alkylation.

The overall process for dodecyl synthesis may be illustrated by the flow at a commercial plant where HF-catalysis is employed. Here, the olefinic stock is gradually added to a mixture of benzene and anhydrous hydrogen fluoride. The rate of addition is carefully controlled to maintain the temperature of the reaction system below 10 C. After addition is complete, the reaction is permitted to continue at the same temperature level. Several hours are required for the batch time. Hydrogen fluoride is finally removed from the system by stripping at atmospheric pressure, and is recycled. The hydrocarbon system is freed of unconverted benzene by topping and is thoroughly washed. Dodecyl benzene is finally recovered in purified form by vacuum distillation. Overall yield is in the range of 85 per cent of theory.

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(Section 2 of Part II of this article will appear in an early issue).

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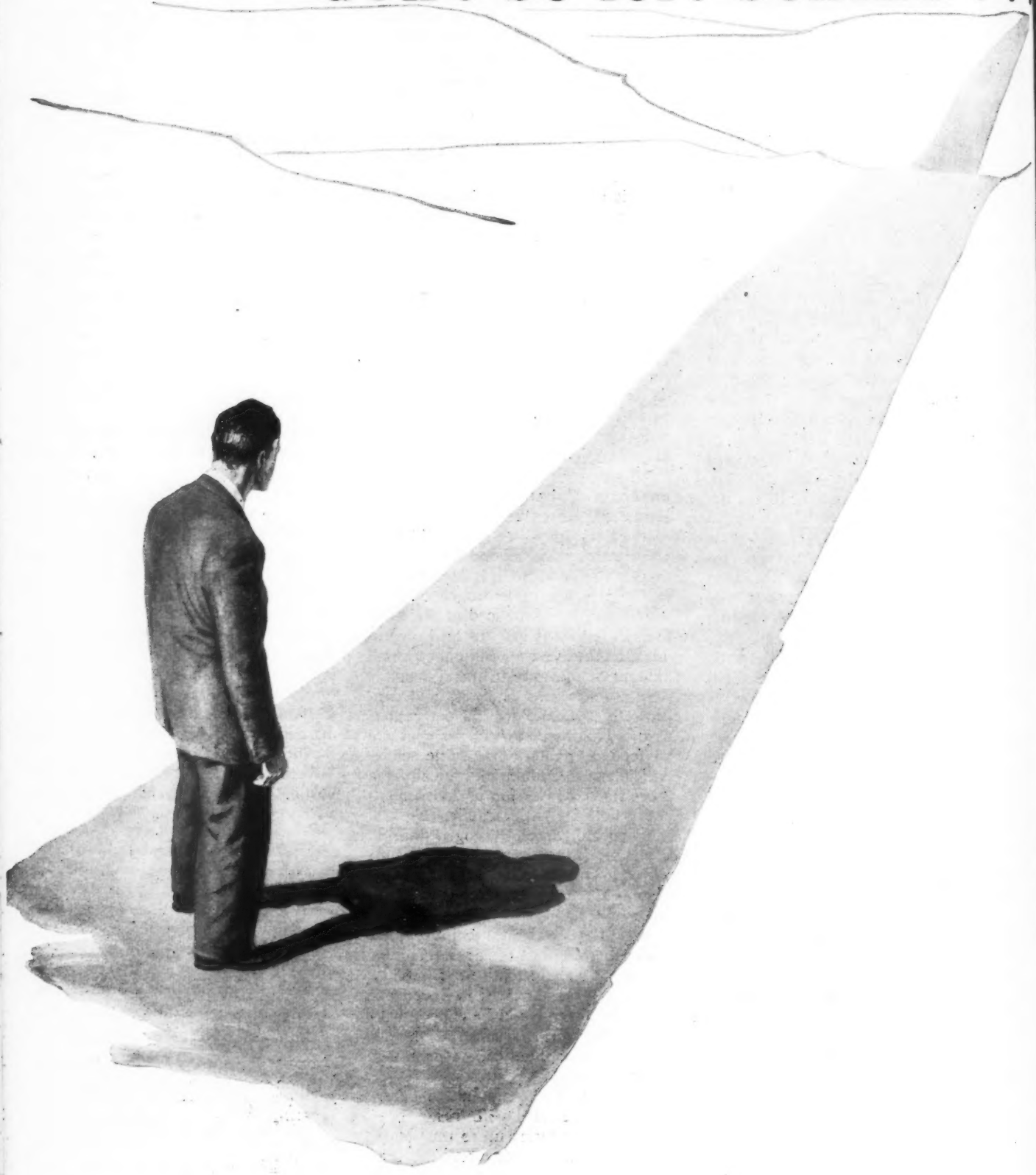

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FIG. 1. Canada's only polythene plastic plant, the $14 million Edmonton unit uses natural gas of nearby Alberta fields

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Canada's only polythene

C. H. Hantho
M. Valois

POLYTHENE, one of the fastest growing products in the field of petrochemicals, is produced by only one plant in Canada. A waxy white plastic in its natural state, polythene resembles a very tough paraffin wax in appearance. It is more familiarly known, however, in the form of the "squeeze" bottle or the film from which transparent bags are made for packaging carrots, apples, and other food products.

Canada's only polythene plant, owned by Canadian Industries (1954) Limited, (C-I-L), is located four miles east of the center of Edmonton, Alberta, on a 300-acre site in the heart of the oil refinery area. (Fig. 1.)

The plant consists of six main groups of buildings, including one to house the administrative offices, one for the power house and cooling water system, an ethylene plant, a compressor and reactor building, a compounding and warehouse building, and a repair shop.

The total cost of the plant upon completion was $14,000,000 for an initial rated capacity of about 12,000,000 lb of polythene resin per year. The present design capacity of the plant is 25,000,000 lb per year, which will take care of Canada's increasing demand for the next few years. The plant employs more than 200 people, most of whom are highly skilled. At full production, the process uses daily approximately 10,000,000 cu ft of natural gas, 8,000,000 gal of water, and 35,000 kw of electricity.

The product of the plant, polyethylene or polythene, is a high molecular weight thermoplastic resin formed by the polymerization of ethylene at high pressures.

Pyrolysis of Ethane Process

The ethylene used in this polymerization reaction is produced by the gas phase pyrolsis of ethane in a unit designed by the Lummus Company. A simplified flow sheet of this process is shown. (Fig. 2.)

The raw material for this unit consists of a "dry" residue gas from the Devon Conservation Plant of Imperial Oil Limited consisting of approximately 75 per cent methane, 20 per cent ethane, and 5 per cent propane. This gas was formerly delivered directly to the City of Edmonton, but owing to its high heating valve, had to be diluted before distribution to the consumers. Now a portion of this stream enters the C-I-L plant where most of the ethane is extracted in the fresh feed absorber. The off-gas from this absorber plus gas from other sections of the unit are blended to the correct heating value for consumer use; some of this mixed gas is used as fuel in the plant and the remainder is fed back into Northwestern Utilities' distribution main.

In the fresh feed absorber the feed gas is passed upward through bubble decks countercurrently to a flow of lean oil. The operating conditions in the tower are controlled in such a way that the lean oil, consisting predominantly of hexanes and heptanes, absorbs most of the ethane but very little methane.

The rich oil so obtained is drawn

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from the bottom of the tower and fed together with additional lean oil to the heater effluent absorber where the ethane and ethylene from the cracking heater effluent gas stream is absorbed. It is in the cracking heaters that the basic chemical reaction of the ethylene plant takes place. This reaction is the high temperature, 1500 F, gas phase dehydrogenation of ethane to ethylene utilizing a feed stream containing approximately 92 per cent ethane, 8 per cent propane.

The residence time of the gas in the alloy steel tubes at this high temperature is very critical. If this contact time is too long, ethylene formed in the initial reaction will polymerize to higher hydrocarbons, which in turn will decompose to carbon and hydrogen. For this reason, the effluent gas stream from the heater is quenched by a direct water spray after the optimum contact time is achieved. This procedure leaves about 50 per cent of the ethane unconverted, which together with the newly-formed ethylene is recovered in the heater effluent absorber.

Acetylene to Ethylene

Before this gas stream is fed to the absorber, any acetylene that might have been formed in the cracking heaters is removed. If the acetylene were not removed at this stage, it would remain associated with ethylene through the distillation section and hence appear in the final product. The removal is accomplished in a Girdler unit where, in the presence of a suitable catalyst and at the correct temperature and pressure, selective hydrogenation of acetylene occurs, yielding ethylene. The hydrogen needed for this reaction is already present in the gas stream from the dehydrogenation of ethane in the cracking heaters.

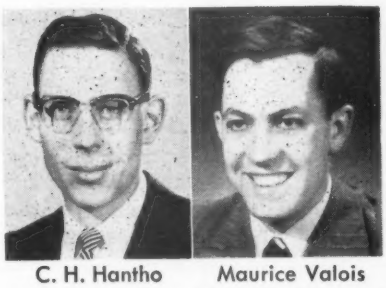
In the heater effluent absorber, gases from the cracking heaters flowing upward meet a downward flow of hydrocarbons consisting of the rich oil from the bottom of the fresh feed absorber and additional quantity of fresh lean oil. The methane and hydrogen from the heater effluent leave the top of the tower while the rich oil leaving the bottom contains all the ethane and ethylene absorbed in the heater effluent absorber plus the ethane absorbed in the fresh feed absorber. This bottom stream then passes to the deethanizer tower where the ethylene and ethane are stripped out of the rich oil and pass overhead whereas the now lean oil is taken off the bottom and is eventually recycled back to the two absorber towers. The overheads from the deethanizer pass forward to the demethanizer where any methane is removed. The bottom stream from this tower, consisting of ethane, ethylene, and a small percentage of propane, is fed to the final fractionation stage where an almost complete separation of the ethylene from the ethane and propane is achieved. The overhead from the fractionating tower, almost pure ethylene, is stored as a liquid whereas the bottoms constitute the feed to the cracking heaters (Fig. 3).

Before being used by the polythene production unit, the ethylene is vaporized from storage, scrubbed to remove any carbon dioxide, and finally is dried thoroughly. This final ethylene product stream is at a pressure of 550 psi and has a purity of approximately 99.85 per cent.

Extensive use is made of heat exchange equipment in the ethylene plant in order to exercise the necessary economy in the heating and cooling phases of the process. This is important because of the widely divergent temperatures encountered in the unit, and, generally, the heat exchangers employed are of the shell-and-tube design. To cope with the basic cooling needs of the plant, a large circulating cooling water system is in operation, but in certain parts of the process lower temperature cooling is required. For this purpose a refrigeration unit rated at 900 tons is included, utilizing a four-stage centrifugal compressor.

Large gas engine-driven compressors raise the gas pressure to the required levels. Two of these compressors are used in the liquefaction of the product ethylene for storage. In this heat pump and heat exchange system, ethylene from the fractionator overhead at 260 psi is compressed to 550 psi and cooled to lose the heat of compression. It then passes through the tube side of the reboiler on the ethylene fractionator column and condenses at 25 F giving off its latent heat to vaporize the ethane at 18 F on the shell side. Hence this exchanger acts as a condenser for the ethylene and a reboiler for the ethane. The resulting liquid ethylene is then piped to storage and the ethane vapor is returned to the base of the tower. By storing the ethylene at 550 psi, a temperature of 25 F must be maintained, whereas if 260 psi were used as the storage pressure a much lower temperature (minus 23 F) would be required to keep the ethylene in the liquid state.

The Authors



C. H. Hantho Maurice Valois

As early as 1940 Maurice Valois was engaged in carrying out extensive research and technical studies on polythene and its manufacturing process with Imperial Chemical Industries, in England. In May 1951, he joined Canadian Industries Limited and, since then, has been closely connected with the Canadian polythene project. Born in England, Valois graduated from Oxford University with honors in chemistry. He is development supervisor of the plastics department of Canadian Industries (1954) Limited.

Charles Harold Hantho has been connected with the C-I-L polythene project since he joined the company in April, 1953. A graduate in chemical engineering of the University of Alberta, he was employed first as a technical assistant at the polythene plant and has recently been moved to Montreal in the same capacity.

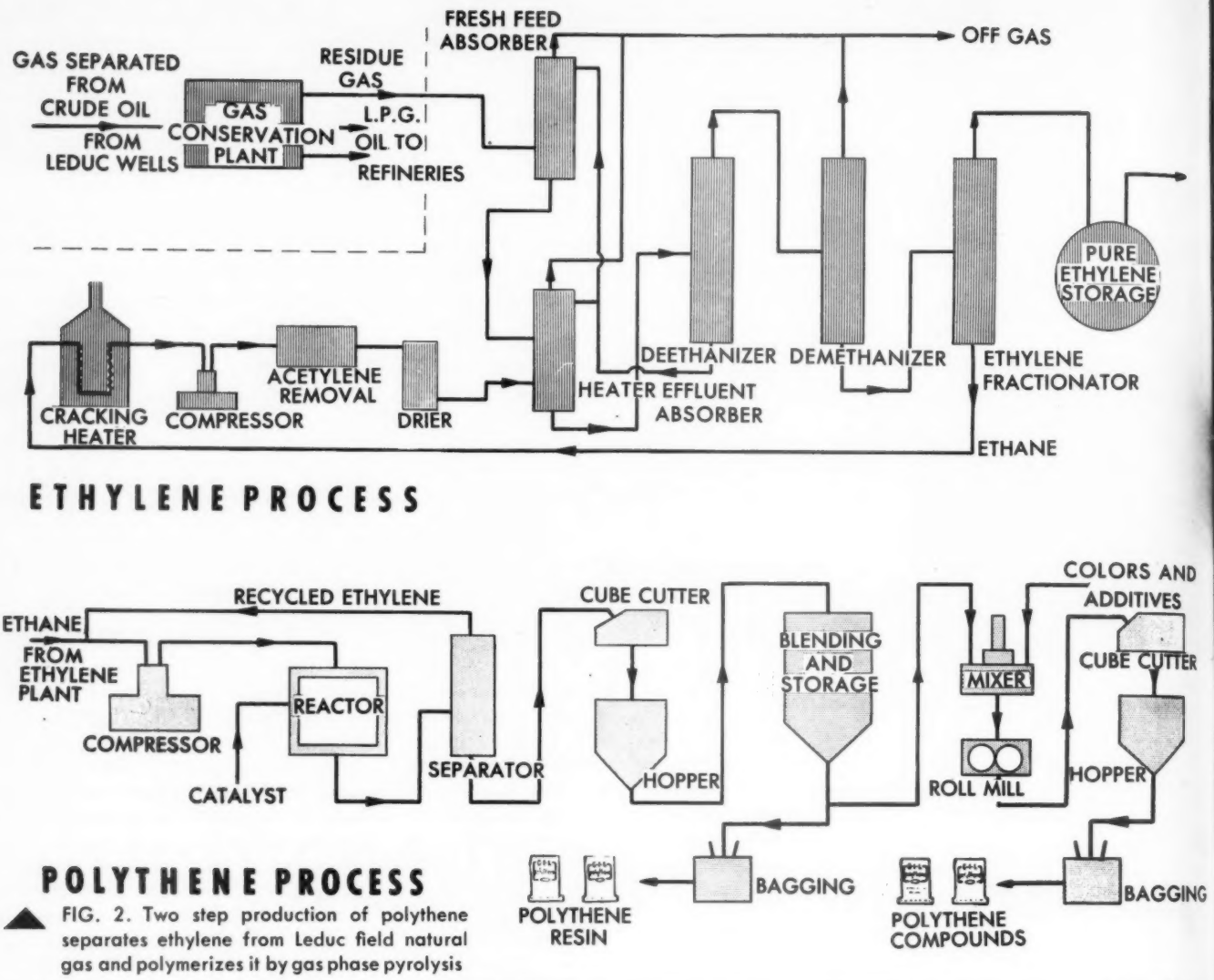


FIG. 2. Two step production of polythene separates ethylene from Leduc field natural gas and polymerizes it by gas phase pyrolysis

Some special problems are encountered in this unit because of the geographical location of the plant. With the low ambient temperatures that prevail in this area during the winter months, special care must be taken to insure a continuous supply of very low dew point instrument air. Extensive use of steam tracing is also needed around the base of water knockout drums, instrument transmitters, field-mounted instruments, etc., which are located in the outside area. Any water or steam lines that are subject to intermittent service must also be continuously purged to prohibit freeze-ups. As the boiling point of ethylene at 550 psi is 25 F, some difficulty has been encountered with liquefaction of the ethylene gas in product lines during low throughputs.

Details of the polymerization process for producing polythene from ethylene remain confidential. It can be said, however, that ethylene is compressed to a pressure in excess of 20,000 psi and fed to a reaction vessel where, in the presence of a suitable catalyst such as oxygen or some other suitable reagent for releasing free radicals, a highly exothermic polymerization takes place. The polythene formed is bled off continuously as a viscous, water-white liquid still above its melting point. Unreacted gas is separated from this liquid and recycled through the system (Fig. 4).

The liquid polythene is then extruded through a nozzle in the form of a ribbon, which on cooling is fed to a dicing machine where it is cut into one-eighth inch cubes. The cubes are then carried into 30-ton silos for blending and storage. From the silos the finished resin is packed in 50-lb capacity polythene-lined multi-wall paper bags ready for shipment (Fig. 5).

Equipment is also installed for compounding polythene resin with antioxidants, pigments, and other additives by milling in a Banbury mixer. The batches from the mixer are dropped into steam-heated hold-up rolls where the milled material is taken off in the form of a continuous ribbon, which once more is cooled and fed to a dicing machine before packing in 50-lb bags for shipment.

Automatic Controls

Extensive use is made of automatic instrument control of operations throughout the process to help insure that the product will conform to rigorous quality specifications. The reaction temperature and pressure must be controlled very carefully, to provide maximum operating efficiency and uniformity of the polymer (Fig. 6). In addition, close surveillance is maintained by the plant's laboratory where samples taken at successive stages of the process are tested. Comprehensive physical property measurements are also made on every lot of finished product prior to shipment. As an additional check, the plant also includes a special product evaluation and development laboratory equipped to carry out all the typical extrusion and moulding operations normally employed by customers in processing polythene into finished articles. This laboratory serves not only in checking the performance of the current product for customer end-uses, but also in the development of improved grades of product for existing and

STATESMEN OF TECHNOLOGY

within the shadows of the ancient Roman Forum an unusual type of diplomacy is at work. Meeting at the Fourth World Petroleum Congress, representatives from many countries have assembled in Rome to discuss mutual problems and to survey the latest developments in the science of petroleum. By this means, the free exchange of ideas and experiences is facilitated among men who are drawn together by the universal desire for progress and success.

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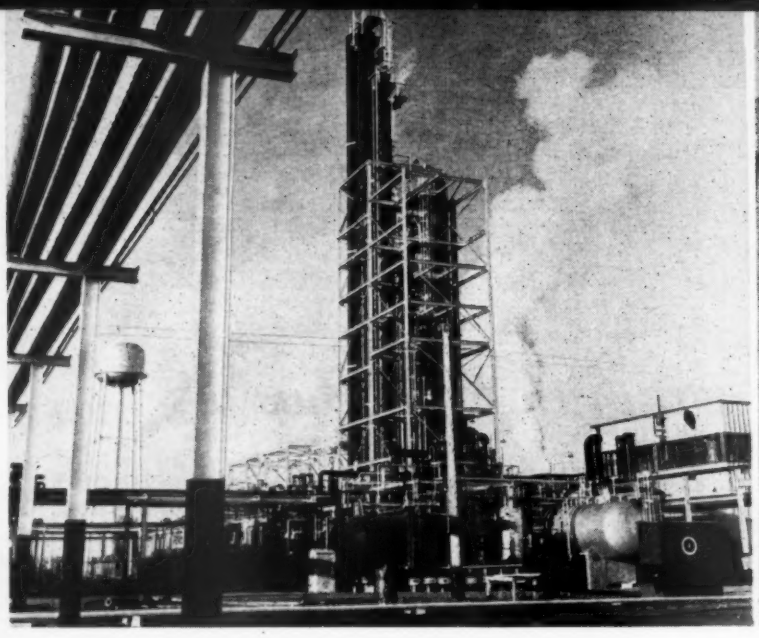

FIG. 3. Tall ethylene distillation towers separate ethylene from other light hydrocarbons prior to polymerization.

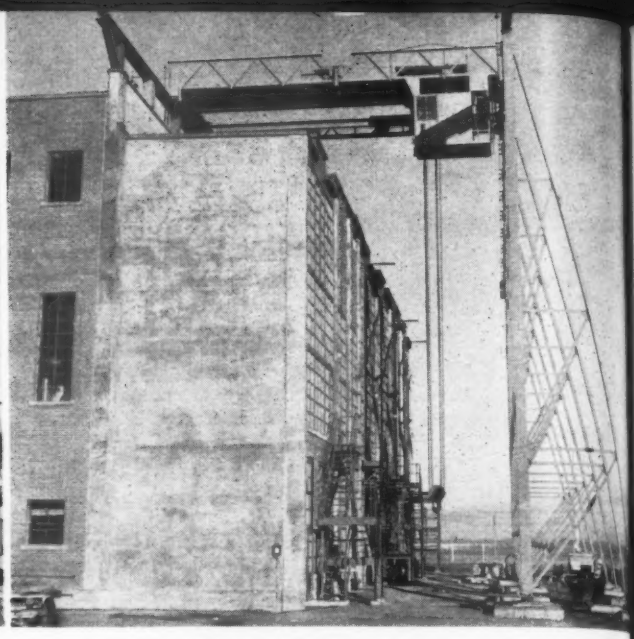

FIG. 4. 20,000 psi plus pressure of polymerization process demands 15-ft thick concrete walls for protection.

newly developed applications. Such work at the plant is backed by a group of chemists and physicists in the company's central research laboratory, working on the more purely scientific problems associated with understanding and thence improving still further properties and processing characteristics of polythene (Fig. 7).

Genesis of Polythene

At this point it may be of interest to review briefly the history of the development of polythene from its discovery up to and including the decision to produce it in Canada.

Polythene was discovered in 1933 in the research laboratories of Imperial Chemical Industries in England, as a chance by-product from an attempt to synthesize phenyl-ethyl-ketone from benzaldehyde and ethylene. The earliest market application survey suggested that this material would make a better insulator for submarine telephone cables than the gutta percha then in use. On the strength of this, a pilot plant was brought into operation in 1937. The first commercial plant was placed in operation by Imperial Chemical Industries in England in September, 1939.

From then until the end of the second World War all production of polythene was directed toward military applications, notably for high frequency electrical insulation in radar systems.

In 1943 two different companies began production of polythene in the United States, both financed by the United States Government, and there, likewise, the output was confined to essential wartime needs. Since 1945, a great variety of uses have been developed for the product, leading to a steep rise in world consumption from some 2500 short tones at the end of the second World War to approximately 100,000 tons in 1953. Of this figure, well over half was made in the United States. By 1956 the demand in the U.S. alone is expected to reach about 250,000 tons per year.

In Canada, prior to the construction of a plant, all requirements were met by imports from the U.S. and the U.K. much of it being distributed by C-I-L. As the Canadian demands increased, preliminary studies were undertaken to explore the possibility of domestic manufacture.

The process of polymerizing ethylene to polythene uses pressures in excess of 20,000 psi—higher than those known to be used in any other commercial operation. This imposes the need for very special large compressors and for the use of expensive alloy steels made to meet exacting standards. The capital cost of such a plant is high and depreciation, particularly for a small plant, becomes the highest individual cost item. Ethylene cost is also a major item since it constitutes virtually the only raw material. The cost of its manufacture is even more markedly affected by the size of the plant. Hence the minimum capacity for the economic production of polythene is high and production in Canada could not be justified until sufficient market had developed.

During 1950 and 1951, market estimates by C-I-L indicated that the total Canadian demand would approach the minimum economic level by 1954. In December 1951, after a very detailed study of capital and operating costs, the decision was made to construct the Edmonton Works.

The most important factor in selecting the location for the plant was the availability of an ample and inexpensive supply of a suitable hydrocarbon feed stock as basic raw material for the production of intermediate ethylene. This source also, if possible, should be close to the polythene market, which of course, is largely in eastern Canada. In investigating the waste hydrocarbon gases from the large refineries at Sarnia and Montreal, it was found that they were already committed or not expected to be available in quantities sufficient to allow for future plant expansion. For this reason, investigations turned to western Canada where natural gas is available cheaply in almost inexhaustible amounts.

As ethane is the most favorable raw material, it was desirable to choose a feed stream with the highest possible ethane content. Such a stream was found available from the Imperial Oil Company's gas conservation plant at Devon, Alberta. At this plant, the offgases from the crude oil wells of the Leduc-Woodbend oil field are processed to remove heavy hydrocarbon butanes and propanes, leaving a residue gas consisting primarily of methane and ethane. With this source, the company could be assured of virtually unlimited ethylene capacity at a saving great enough to offset the heavy freight charge incurred in sending polythene by rail from Edmonton to the principal markets in eastern Canada.

Finally it might be well to discuss the commercially important properties of polythene and some of its main applications. The term polythene (or polyethylene) covers not one, but a whole family of polymers consisting of large essentially saturated hydrocarbon chains, the length of which may be varied to yield polymers of different molecular weights. Most of the present-

day uses, however, are confined to a relatively narrow group of polymers, of average molecular weight in the region of 20,000-40,000, depending on the way it is measured.

Polythene is tasteless, odorless, and non-toxic and is the lightest solid plastic, being the only one with a density less than that of water. It is characterized by outstandingly good dielectric properties, especially at high frequency; in fact, during the second World War polythene made airborne radar possible.

Polythene has a high impact strength, and good shock resistance, but is flexible even at sub-zero temperatures. It exhibits excellent resistance to strong acids and alkalis and is not dissolved by any solvent at room temperatures. There are certain limitations however, in the use of polythene without additives that should be mentioned.

A major one is the deterioration in the properties caused by oxidation through thermal or sunlight effects. The problem of thermal oxidation has been overcome largely through the addition of small amounts of specially developed anti-oxidants while the sunlight problem has been met satisfactorily by the addition of 2 per cent fine particle channel black, which acts as an effective light screen when well dispersed in polythene.

Another limitation is the susceptibility of polythene to "environmental cracking." Cracking may occur when polythene is biaxially stressed in contact with certain organic polar liquids (e.g., alcohols, aldehydes, ketones, acids, esters) or aqueous solutions of alkalis or surface-active agents, even though these compounds normally do not react with polythene.

The probability of environmental cracking occurring with polythene from a given source decreases with increased molecular weight so that this problem can be minimized by the careful selection of the proper grade.

A third major limitation of polythene is its relatively low upper operating temperature. It must be noted, however, that although polythene loses many of its useful properties at elevated temperatures, it will hold its form up to within a few degrees of its melting point when subjected only to low loads.

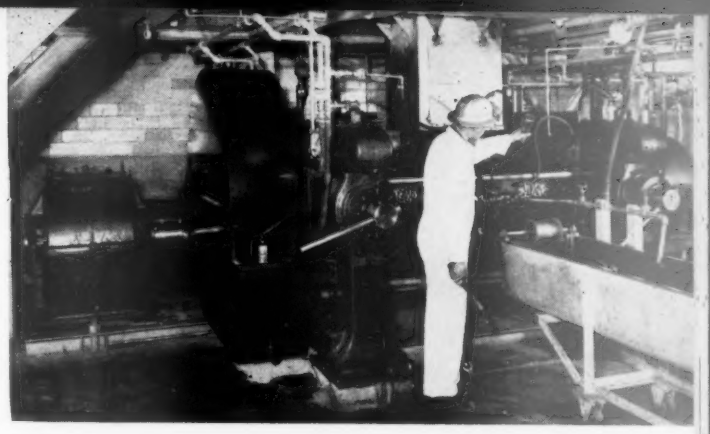

FIG. 5. In Banbury mixer polythene resin is compounded with anti-oxidants, pigments, and additives and dropped on steam-heated rolls

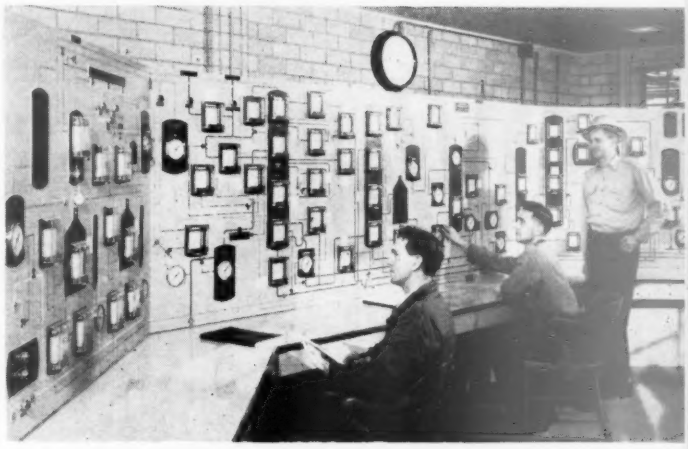

FIG. 6. Graphic panel illustrates the latest in automation. A twist of a knob on board establishes or realigns operating conditions

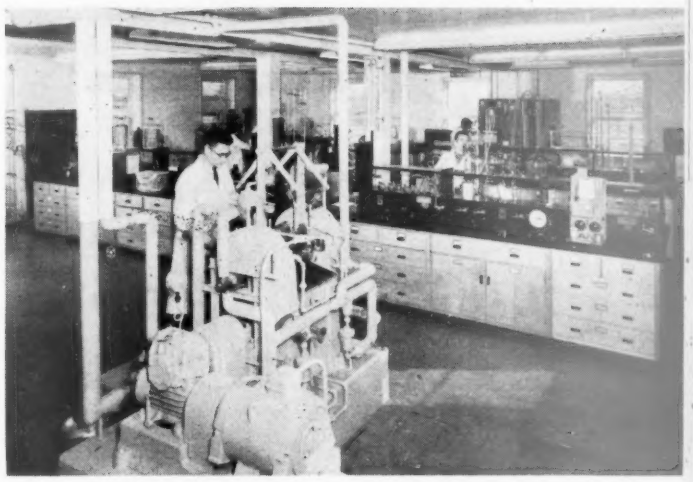

FIG. 7. Control laboratory at CIL plant checks products at each step from raw material to finished plastic

End-Use of Polythene

The uses of polythene can be broken down into four major categories:

(1) Consumer goods,
(2) Industrial goods,
(3) Packaging, and
(4) Electrical applications.

In the field of consumer goods, polythene is used either naturally or compounded in the manufacture of pipe. The bulk of the pipe is used for cold water distribution in private rural water systems, but some is used in mines and other industrial applications. Also in the consumer field a wide assortment of houseware, kitchenware, and toys are produced from polythene, including such items as canister sets, refrigerator bowls, tumblers, wash basins, toy cars, trucks, etc.

In the industrial goods field polythene is used to produce various beltings, strippings, custom mouldings, and extrusions.

In packaging applications, polythene is used to produce film, squeeze bottles, various moulded containers, closures of all types and sizes, coated papers, paperboards and foils, laminates, and as a component in various wax blends that, in turn, are used to coat papers such as breadwrap.

The electrical applications could have been included in the industrial goods field but they are of sufficient importance to be considered separately. Polythene is used as a dielectric and sheathing in various types of wire and cable, including high frequency coaxial cables, army field wire, TV lead-in wire, drop wire, weatherproof line wire, submarine cable, and various telephone cables. * * *

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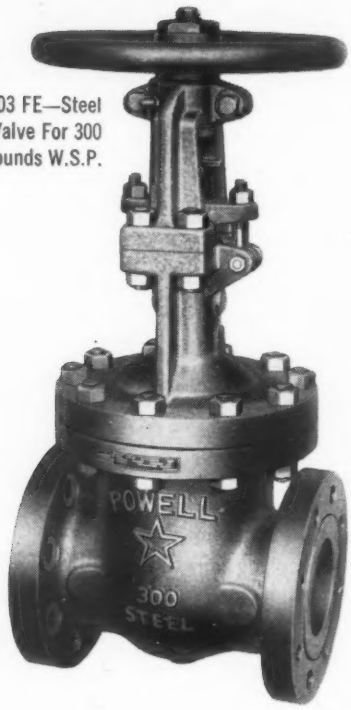

FIG. 3003 FE—Steel Gate Valve For 300 Pounds W.S.P.

FIG. 1561—150-Pound Steel Swing Check Valve.

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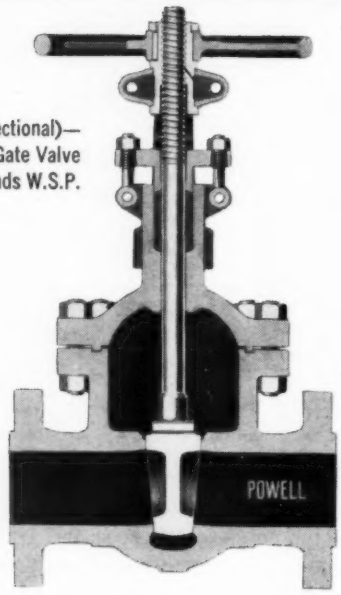

FIG. 6003 SS (Sectional)—Alloy Steel Gate Valve For 600 Pounds W.S.P.

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FIG. 1559—150-Pound Steel Lubricated Plug Valve.

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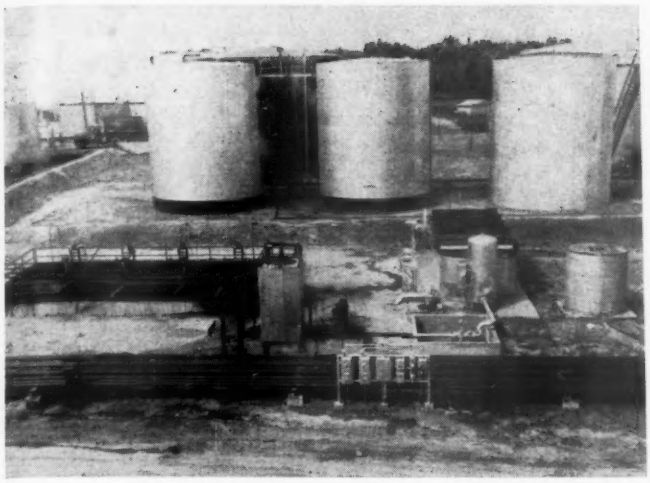

▲ FIG. 1. Full view of dissolved-air flotation separator that handles peaks of 500 gpm effluent flow and reduces pollutents to 10 ppm at Leonard Refineries

▲ FIG. 2. Unit showing 190 sq ft area of retention tank and 4 of the 9 flight-scrapers that skim oily froth rising to top of 6750 gal capacity flotation tank

Refinery Waste Water Cleaned by Flotation

C. E. Fiske and Paul Mernitz
Leonard Refineries, Inc.
Alma, Michigan

400 gpm effluent of high oil content reduced to 10 ppm in 500 gpm dissolved air separator

AFTER a thorough investigation, the management of Leonard Refineries, Inc., in Alma, Michigan, decided to add to its facilities for waste water clarification. Average effluent flow of 180/200 gpm, with peaks near 400 gpm, made it impossible any longer to hold the oil content of the water below 80 ppm at the trap outlet. Further clarification with hay dams and manual skimming was of doubtful and erratic efficiency and quite costly.

Of the various commercial separators that were offered, the dissolved-air flotation process for further reducing the oil and grease content looked most attractive for three reasons. First, the installation could be a compact package unit, offering good clarification with only about 18 minutes retention time at full flow. Second, although alum or other chemical feed was to be used for the best oil reduction, it was claimed that the dissolved-air flotation principle could still yield a substantially better effluent water even should the chemical feed system fail. Third, there was an excellent chance that the separated oily skimmings could be kept to volumes that would not require any dewatering system for sludge disposal. As the proposed air-flotation unit was competitive with sedimentation clarifiers at the same throughput rate, this last consideration meant that the capital investment might be held to a minimum (Fig. 1).

Accordingly, a 500 gpm dissolved-air flotation separator* was brought on-stream at Leonard on July 11, 1954. It has been operating continuously since that time, handling varying compositions of waste water at 150 to 500 gpm flow, and yielding relatively clear sparkling water of below 10 ppm oil and grease at an alum feed rate of 65 ppm.

Operation of Separator

The unit is installed downstream of the existing API trap, which it supplements rather than replaces. It picks up the water and pumps it into a 2-3 minute retention tank in which it is saturated with dissolved air at 25-35 psig.

*"Colloidair," manufactured by Bulkley, Dunton Processes, Inc., of New York.

EXCLUSIVE

Chemical feed, if used, is continuously proportioned to the waste flow and solution-injected on the pressure side.

Passing from the retention tank through a pressure release valve, the water enters the inlet end of the flotation tank where countless colloidal air bubbles come out of the solution. These adhere to the oily particles to sweep them to the surface. Chemical floc-formers aid in this operation by forming a structure that effectively holds the air in an oil-bearing froth.

Moving from the inlet end, the water flows over a submerged weir through a relatively non-turbulent flotation chamber of 190 sq ft area (in the 500 gpm size) and 6750-gal capacity, from which nine flight-scrapers on an endless chain skim the oily froth over another sludge-recovery apron weir

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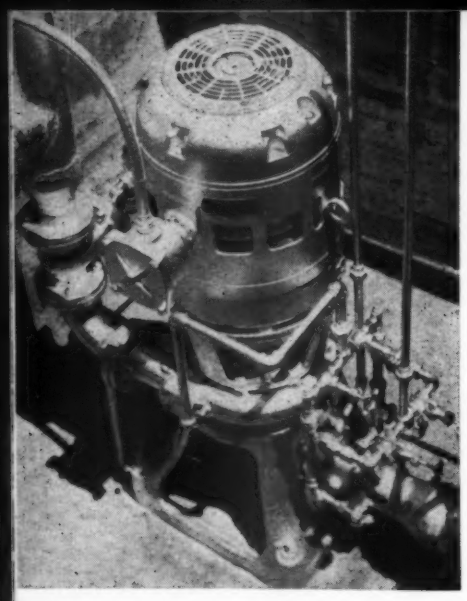
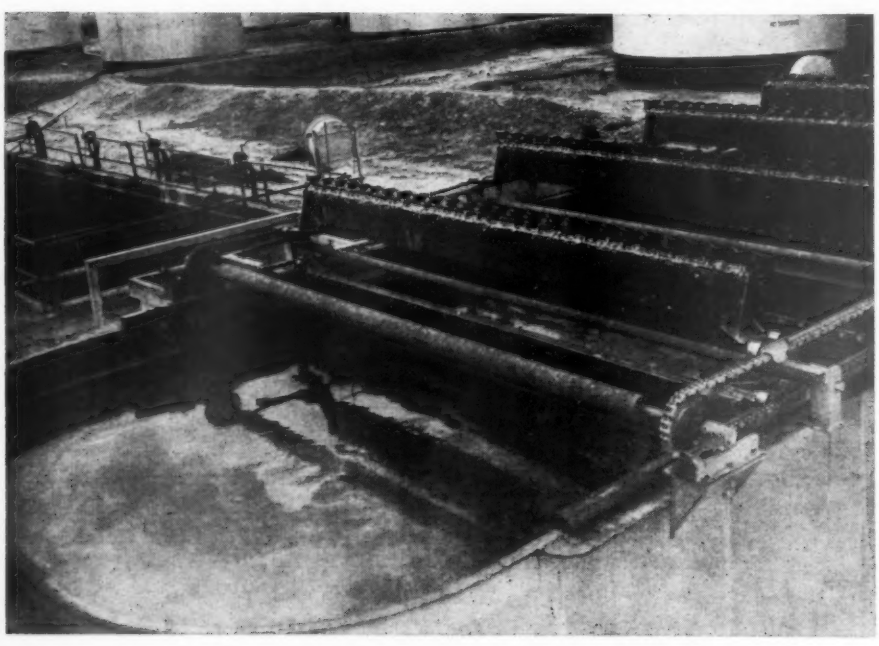


FIG. 3. Main 500 gpm at 90 ft head pump takes flooded suction at all times by means of automatically maintained level above inlet through recycling of some water

FIG. 4. Endless belt moves flight-scrapers; edged with a 6 in. neoprene sheet, they sweep the 20 ft flotation chamber at 16 in. per minute. Retention time is under 40 minutes at an average flow of 180 gpm



(Fig. 2). Clarified water is continuously withdrawn from a series of four transverse collecting pipes near the bottom. The withdrawal tubes make a right-angle turn upward through the clarified-water collecting basin, and are adjustable in vertical rise to permit level control of the flotation chamber. Discharge from the clarified water collecting basin is over a flow-measuring weir, from which the water goes to outfall, recycle or further treatment.

The main pump in this system is rated at 500 gpm at 90-ft head, and must take flooded suction at all times. In order to provide for variable flow of waste into the system, the suction pit is automatically maintained at constant level above the pump inlet by recycling some of the water. The recycle rate is controlled by a pneumatic valve actuated from the liquid level float in the suction pit. For gross overload exceeding 500 gpm, such as might eventuate from very high ground water runoff, a short-circuiting overflow is provided in the suction pit itself well above its normally maintained level (Fig 3).

Adjustment to Maximum Efficiency

After completion of a shakedown run in the presence of the vendor's engineer, the better part of a month was spent by Leonard personnel in determining water characteristics at varying rates of chemical feed, air pressure, scraper-flight speed, and flotation tank levels.

The criteria were: (1) Acceptable oil and grease removal (less than 10 ppm), (2) minimum practicable sludge volume, and (3) most economical chemical feed rates. After each variation, a day or two was allowed to attain steady state conditions.

The best balance of these conditions bearing directly on residual floatable oil and grease were found to be as follows:

1. Alum feed, from a one pound per gallon solution, about 60 ppm. In general, the pH averaged about 8.3 with swings to 6.5 and 9.7. Alum in excess of 60 ppm offered no advantage, just adding to the cost and to the volume of the recovered sludge. Above pH 9, alum floc tended to peptize; i.e., the floc particles fell out and appeared in a non-coagulated form in the clarified effluent. The result was "black water." The violent pH swings were quickly traced to caustic neutralizer plant dumps and to boiler house softener wastes, both non-oily streams that have been since piped directly to waste. Although 60 ppm of alum may not be the absolute minimum, it is felt that the chemical cost of $3.34 per day for treating 260,000 gal of water is not excessive, and will provide a good margin of safety, as emulsified oil is occasionally a factor.

2. Scraper-flight speed. Best results have been had with the minimum lineal speed of 16 in. per min. At the average flow of 181 gpm, average retention time is 37.5 min. As the skimming basin (flotation chamber) is 20 ft long, the minimum flight speed is 15 min per traverse. It is felt that such a relation offers least chance of turbulence at the skimmed layer. The danger of increased fallout of floc into the effluent at the downstream end has not materialized.

3. Design air pressure of 25-35 psig has been maintained. During times of lower-than-average throughput, a relatively large proportion of water recycles to the suction pit to maintain flooded suction. Under these conditions, a pressure drop of up to 20-30 per cent is experienced in the retention tank, which means that less air is dissolved in the raw water. As less water with its load of oil is being processed at such times, however, the net effect is to maintain adequate flotation.

The best retention tank level was found to be one at which the oily sludge was concentrated to approximately 2 per cent of oil. This adjustment is a rather coarse one, made by adjusting the length of the clarified-water riser pipes. Attempts to concentrate the sludge further by lowering the flotation tank level led to increased fallout of oil-bearing flocculant because it was being skimmed inefficiently.

Design Difficulties

Little trouble has been encountered in a mechanical sense, all of a minor nature. The neoprene scraper blades have lost much of their strength by continued contact with oily water, and

have swollen and corrugated badly in the three month's time. An experimental Saran formulation has been obtained and was recently installed on one of the flights. Its performance, while satisfactory for one month, cannot yet be judged in comparison to the neoprene. Minor alignment difficulties have occasionally caused the flight scrapers to untrack over idler cogs.

Floatable Oil Removal

The analytical method used in reporting oil and grease contents was developed by Pomeroy[1] for floatable oil and grease. This method minimizes sampling difficulties, avoids the errors caused by significant solubility of inorganic salts in the direct ether extraction method, and is well adapted for routine testing. It is necessary, however, to acidify the grab samples before allowing flotation. The Noll[2] method was discarded when it was found that addition of $FeCl_3$ solution, preparatory to producing $Fe(OH)_3$ floc *in situ*, oxidized sulfide ion to sulfur, which showed up in the ether extract of the floc-fixed oil.

Over a 2-week period of test, the water characteristics summarized in Table I was found, with extremes as indicated. Each instance of residual grease and oil over 10 ppm was found to be associated directly with improper pH conditions, usually a caustic neutralizer plant dump. With the diversion of this non-oily stream it is felt that oil-removal and clarification yields completely acceptable water, well within the limit of oil contamination set up by state authorities.

Effect On Other Properties of Water

Hopes were entertained that the intimate contact of the waste water with oxygen, such as this system employs, would substantially clean up the water with respect to phenol, sulfide, and BOD. Aside from the obvious improvement in BOD made by removal of organic oily materials, that hope has not been realized. If biological oxidation of such contaminants was indicated before oil and grease removal, it will be no less necessary after, in the experience of Leonard. However, the prior reduction of oil and grease concentration is a definite forward step in the successful operation of trickle filtration, which many refineries will find necessary for phenol removal.

No analytical data on removal of non-oily solids has been reported; however, the clarified water samples taken have invariably been clear and sparkling, with no visual evidence of heavy sediments going to outfall.

Sludge Disposal. At the present throughput rate, Leonard is recovering some 30-40 gpd of oil and grease, whose bulk is augmented in the recovered sludge tank by flocculant and temporarily entrained air. Total waste in this tank amounts to some 80-100 bbl per day, which is, of course, a more dilute concentration than the 2 per cent of oil cited above. The difference was believed to be due to temporary surges of high levels, for which the unit does not compensate. This volume has been pumped off to ponding areas for disposal where it has offered no problem. It has been more automatic, using a float controlled 3-hp rotary pump.

Investment and operating costs. The 500 gpm unit installed at Leonard was purchased for about $23,100 including the sludge transfer pump, fir chemical tank, and chemical feed system. Additional piping, concrete pads and drywell, and other materials brought the total material cost to about $26,550. Installation labor was about $2,425, to a total of nearly $29,000.

Power costs are about $5 per day for the four pumps required. Chemical feed (alum) costs about $3.34 per 24-hr day, or $0.0128 per 1000 gal. Maintenance, alum solution makeup, and miscellaneous attention amounts to about 1½ hr or $3 per 8-hr day. ★ ★

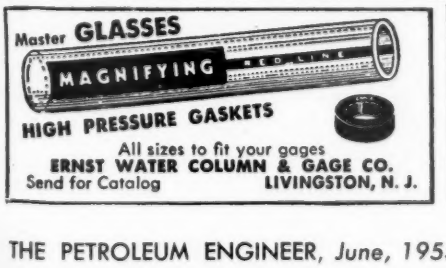
TABLE 1. Refinery waste water characteristics — 2 week test run.

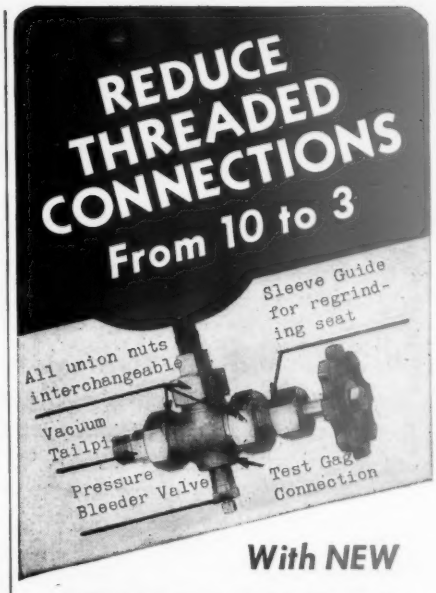
Property	"Colloidair" Influent water			"Colloidair" Effluent water		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Rate of flow, gpm	110	181	412		Same	
Floatable oil and grease, ppm	28	86	573	2.2	4.0	36
Water temperature, deg F[1]	—	—	—	103	115	125
Sulfide (Asppm S)	40	281	1,710	18	208	406
pH	5.7[2]	8.4	9.7[2]	5.7[2]	8.3	9.7[2]
Specific conductance, MHoS	1050	2115	10,000[2]	1200	2200	8000[2]

[1] Period in Mid-July.
[2] Related to caustic neutralizer or softener system dump.

[1] "Floatability of Oil and Grease in Waste Waters," by Richard Pomeroy, *Sewage and Industrial Wastes*, Vol. 25, No. 11, 1304-7, November, 1953.

[2] "Fixing and Determining Oil in Feed Water and Boiler Water," C. A. Noll, and W. J. Tomlinson, *Ind. Eng. Chem. Anal. Ed.*, Vol. 15, pp 629-632, October 1943.





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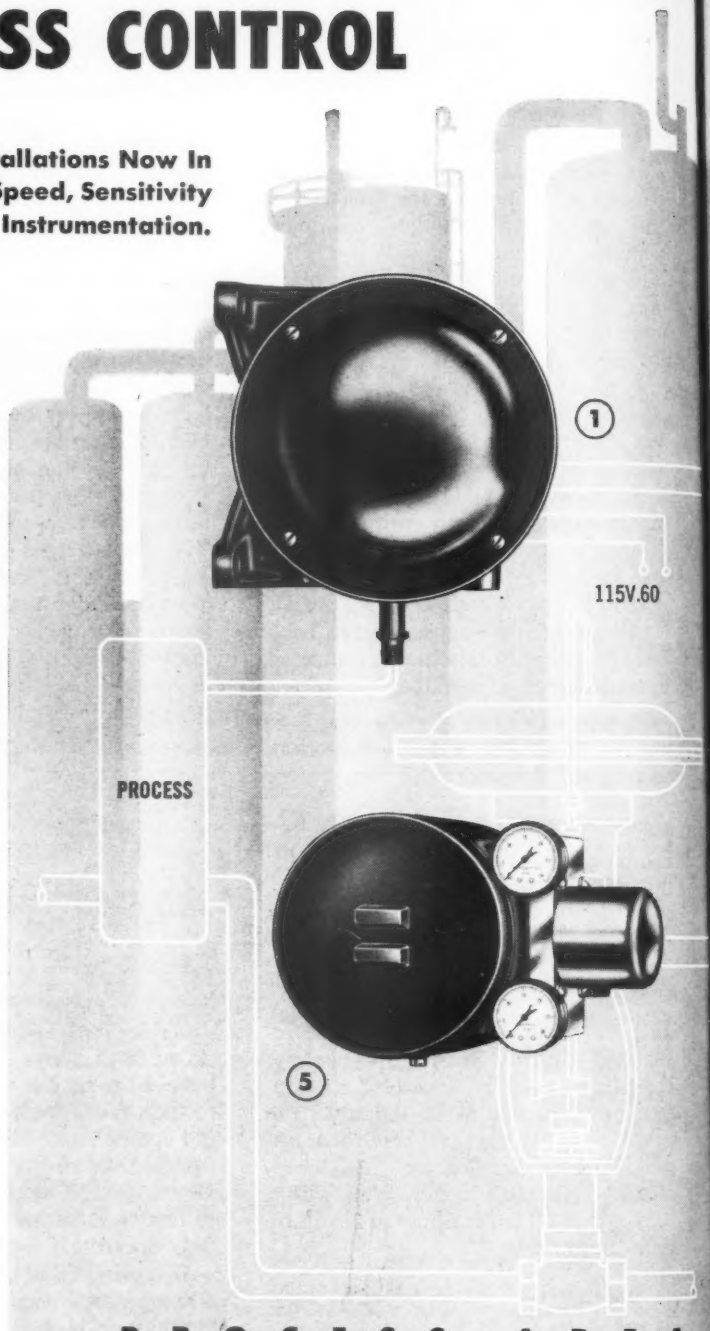
Minimum installation or maintenance investment in transmission lines, air compressors, filters, pressure regulators, dryers.

**Names and locations of installations available upon request.*



THE 'MICROSEN' BALANCE, the "nerve center" of 'American-Microsen' Instruments, is a simple, electro-mechanical servo-mechanism. It operates on the force-balance principle to produce a high-level direct current signal that is not affected by any normal electrical or ambient condition.

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1. **TRANSMITTER.** Types to transmit measurements of temperature, pressure, differential pressure, liquid level, flow, pH, oxygen concentration, gas analysis, etc.
2. **RECORDING SET STATION.** Records on strip chart or card and compares the measured variable with the control point setting. Error signal is transmitted to the Controller.
3. **CONTROLLER.** An electronic amplifier with simple feedback circuits to produce calibrated proportional, reset and rate control actions. (Rate action added by plug-in unit.) Resulting control signal is fed to the Manual Control Station.
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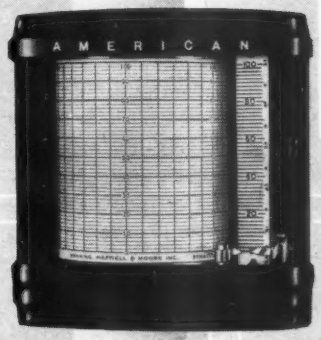

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The Nature and Composition of PETROLEUM

CHAPTER III

V. A. Kalichevsky*

This chapter is presented here, early in the series, because any understanding of petroleum refining and the nature of its products must be based on knowledge of the chemical composition of petroleum itself.

Articles in this series will take up the nature and the methods of handling emulsions, or intimate mixtures of water and petroleum, ways of "breaking" these emulsions. Also discussed will be the composition of natural gas and the recovery of light liquid hydrocarbons. —*Editor.*

Nature of Petroleum

To most of us the word "petroleum" is associated with a vile-smelling, dirty, thick liquid from which we should keep away if we want to stay clean. We can hardly believe that a substance of such an uninviting nature can be converted into a vast number of extremely valuable products, each very different from the others, and retaining none of the objectionable characteristics of the crude oil. This transformation is brought about by refining processes, which have undergone many basic changes in the course of the last few decades. These processes involve the use of huge installations which are both complicated and dramatic in appearance.

Many different kinds of crude oil exist. For example, Pennsylvania crude oil is quite different from Texas or California crude oils, in spite of the fact that they might appear identical to a superficial observer. Even the crude oil obtained from the same field but from different depths may not be the same. Some crude oils contain larger or smaller quantities of a black, semi-solid material familiar to everybody as asphalt. Others, which are usually lighter in color, congeal readily, but begin to flow with ease after they are heated above a certain temperature. When such crude oils are cooled they deposit a light-colored, crystalline or semi-crystalline substance that is nothing more nor less than ordinary paraffin wax. Still other crude oils contain both asphalt and paraffin. Consequently crude oils are classified as being either asphalt-base, paraffin-base, or mixed-base.

The presence of asphalt or wax is not the only characteristic that distinguishes asphalt-base from paraffin-base oils. Gasoline from crude oils rich in asphalt performs better in automotive engines than gasoline from crude oils rich in wax. Kerosine from paraffin-base oils, however, is of higher quality and lubricating oils retain their "body" and do not thin out on heating as fast as the asphalt-base oils. The respective products from the mixed-base crude oils have intermediate properties compared to those of the asphaltic and paraffinic oils.

Classification into asphalt-base, paraffin-base, and mixed-base crude oils survived up to the present time and is quite common among the refinery men. It is far from satisfactory, however, because it is of qualitative and not of quantitative nature, and fails to divulge the real characteristics of the different crude oils. Besides some of the crude oils fail to show the continuity in the quality of their various fractions that is implied by such classification.

Petroleum consists largely of carbon and hydrogen compounds that differ widely in their properties. The relative quantities of the various compounds present in a crude oil determine the chemical nature of the oil with which asphalt and wax are associated. Chemists gradually realized that no two crude oils are alike, thus making an exact classification an impossibility. This also means that each crude oil presents its own problems, particularly when attempts are made to rework it into high-grade products. Some crude oils may be well fitted for certain specific purposes, but others may be worthless in this respect, or yield products of inferior characteristics irrespective of the method employed in refining them. The contents of various fractions in crude oils are also far from uniform. This may be seen from the data presented in table 4.

Table 4. Variations in Composition of Crude Oils.

Oil field	Composition, % by volume				
	Gas and gasoline,	Kerosine,	Gas, oil,	Lubricating, oils	Residuum
Dorcheat-Macedonia, Ark.	87.7	9.5	none	none	2.8
Helm, Calif.	88.3	3.7	5.2	none	2.8
Bradford, Penn.	36.8	16.7	8.2	15.2	23.1
East Texas, Texas	35.7	4.4	20.7	16.4	22.8
Kern Front, California	0.7	none	24.4	20.4	54.5
Iberia, La.	3.5	none	51.8	20.5	24.2

The refiner is, therefore, careful in selecting the crude oils he is buying with respect to the quantity and quality of the materials that he can recover on processing. It also explains the differences in prices between crude oils obtained from the various oil fields.

Hydrocarbons: Chain and Ring Types

Chemically the crude oils may be considered as mixtures of various compounds of carbon and hydrogen, which are known under the general name of hydrocarbons. In addi-

*Consulting Chemical Engineer.

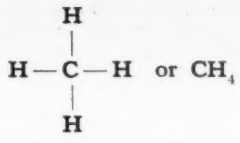
The wide variations in the proportions of various main products found in different crudes are shown graphically for two crudes from the same state, California, one a very "light," the other a very "heavy" crude. "Light' refers to a relatively low-boiling, high API gravity material; "heavy" denotes a high-boiling, low gravity, often viscous liquid.

tion they may contain compounds of sulfur, nitrogen, oxygen, and even traces of metals, such as calcium, iron, aluminum, copper, silver, gold, vanadium, and others. For purposes of simplicity they may be regarded as impurities.

The carbon content of crude oils varies between 84 and 87 per cent and the hydrogen content between 11 and 15 per cent. Oxygen, nitrogen, and sulfur combined, account for one-half to five per cent and seldom exceed the latter limit. Although hydrocarbons consist of only two elements, they vary extremely widely in their properties. This happens because their characteristics change with the number of the carbon and hydrogen atoms and their arrangement in the molecule. In general they may be divided into two major classes: Straight-chain (aliphatic) and ring (naphthenic and aromatic).

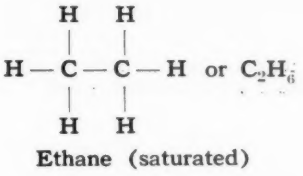
When atoms combine to form a chemical molecule, each carbon atom is capable of holding or attaching to itself four hydrogen atoms, or their equivalent. When it does so, the carbon atom is said to be saturated. The attractive force holding the atoms together, and indicated by a straight line, is called a bond, or linkage. The basic nature of this attractive force is probably electrical.

Therefore the simplest chemical compound containing carbon and hydrogen is:



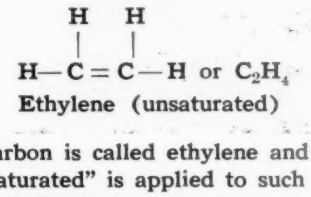
This hydrocarbon is called methane. It constitutes by far the largest proportion of the so-called natural gas that is found in the oil fields and is closely associated with petroleum.

The next simplest hydrocarbon, which is also a gas, contains two carbon atoms joined to each other in the following manner:

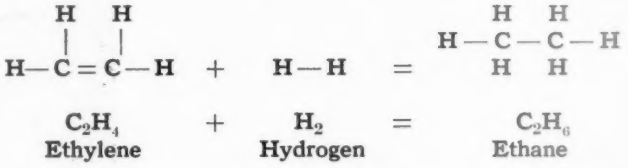


This gas is known as ethane and is also one of the constituents of natural gas. In this case each carbon atom holds three hydrogens, the fourth being replaced by the second carbon atom. Further members of this series of saturated hydrocarbons are formed in a similar way, with more carbon and hydrogens extending out in a straight-chain structure; thus a large and important group of saturated hydrocarbons, known as paraffin hydrocarbons, is built up. This straight-chain group with its various ramifications is often referred to as the aliphatic type of hydrocarbons.

In the above compounds the carbon atoms are united between themselves by only one dash, which is considered as representing one chemical bond. However, a very large group of hydrocarbons contains atoms that are joined by two or more chemical bonds, i.e. by two or more dashes as these bonds appear in chemical formulas. This may be visualized from the following picture of the simplest member of this series:



This hydrocarbon is called ethylene and is also a gas. The term "unsaturated" is applied to such hydrocarbons, because one of the bonds between the two carbon atoms is free to attach itself to some other element if it becomes available; thus the double bond changes into two single bonds and a saturated molecule is formed. For instance, if hydrogen is present, ethylene may add it and form ethane. The reaction proceeds as follows:

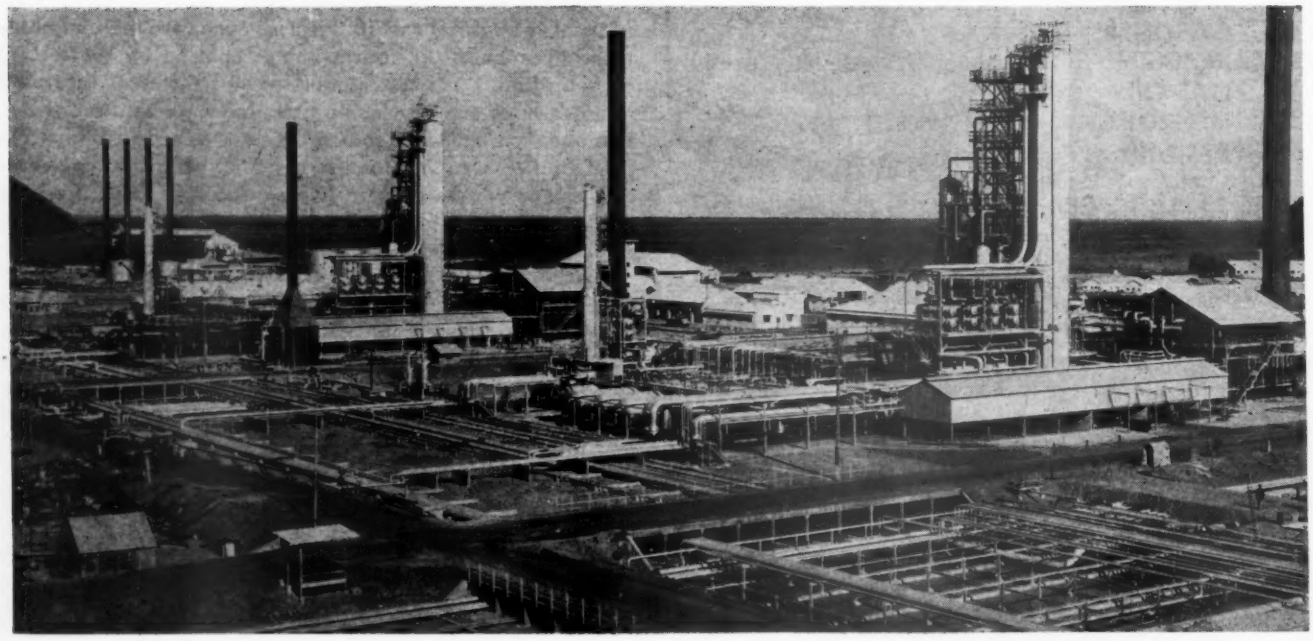


Another equally important series of hydrocarbons is known as the aromatic group, so called because of their characteristic odor. These differ radically from the straight-chain or aliphatic group. They contain six carbon atoms forming a closed ring with double bonds between each second pair of carbon atoms. The simplest member of this series is the well known substance benzene, or benzol. Graphically the benzene molecule may be represented as follows:

REFINING FUNDAMENTALS

These three photos illustrate the principal steps in the production of the major refined petroleum products:

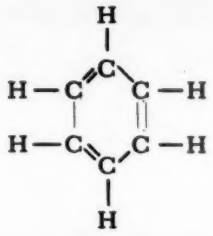
A. Crude is brown to black, more or less viscous, and has an unattractive odor.



B. In a refinery such as this Aden, Arabia, plant, crude is separated, treated, has its molecules rearranged to make the main products of commerce.

C. And here we have the consumers of the major products of petroleum and natural gas; motor fuel in the fuel tank; lubricating oil in the crankcase; lubrication greases on chassis and other bearing surfaces; synthetic rubber in tires; petrochemicals (resins, etc.) in the finish; asphalt on the road under the wheels.

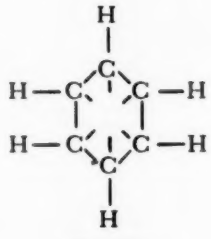
XUM



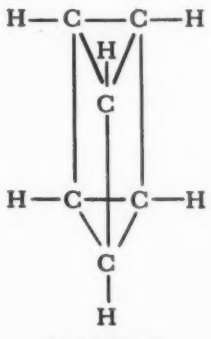
or C_6H_6

Benzene (unsaturated)
Kekule and Loschimdt formula

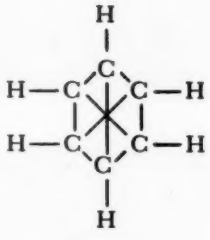
The formula shows that benzene contains three double bonds which indicates that it must add hydrogen or other elements easily. Actually, they can be added to benzene but with a much greater difficulty than to the unsaturated open-chain hydrocarbons. For this reason it is doubtful whether the double bond in the benezene molecule and in the rest of the unsaturated hydrocarbons is the same. In order to account for this chemical behavior several structural formulas for benzene were proposed by various chemists as shown below:



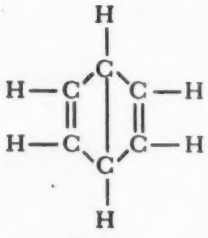
Baeyer



Ladenburg



Baeyer



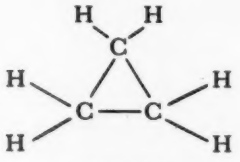
Dewar

Possible structures of benzene molecule

Each formula shows a different way that the carbon atoms might be attached to each other in the benzene molecule. It also explains the behavior of benzene or its derivatives in some of the chemical reactions but not in all of them. As a result of an intensive research Baeyer came to the conclusion that the ring structure of benzene may vary with the type of compound containing benzene as a base. The formula of Kekule and Loschmidt is used in the present discussions because it is the simplest but with the understanding that the double bonds in benzene are not of the same type as the double bonds in the non-aromatic compounds.

The complexity of the aromatic series of hydrocarbons may be visualized if we try to imagine the number of substances that can be formed by replacing one or more hydrogen atoms with other groups containing both carbon and hydrogen, as was shown in connection with the saturated hydrocarbons. Such "benzene derivatives" are numbered in the thousands.

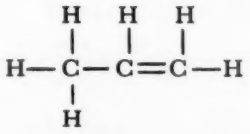
Another group of hydrocarbons, known as naphthenic hydrocarbons, is characterized by a ring structure similar to that of benzene, but they may or may not contain double bonds and have a variable number of carbon atoms in the ring. The simplest member of this series is cyclopropane, a gas occasionally found in natural gas; it is sometimes used as an anesthetic.



or cyclo-C_3H_6

Cyclopropane (saturated)

It may be noted that cyclopropane is a saturated hydrocarbon while propylene, the second member of the ethylene series, is unsaturated although both hydrocarbons have the same number of carbon and hydrogen atoms.

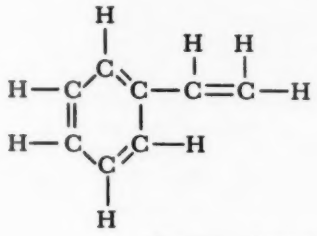


or C_3H_6

Propylene (unsaturated)

The boiling points of the two hydrocarbons are different. Propylene boils at —53.7 F and cyclo-propane at —27.4 F.

The complexity of hydrocarbon molecules increases rapidly with increase in the number of carbon atoms. A vast number of hydrocarbons are known that may be classified within more than one group. For instance a compound such as styrene may be considered as being both an aromatic and a straight chain unsaturated hydrocarbon.



or $C_6H_5 \cdot C_2H_3$

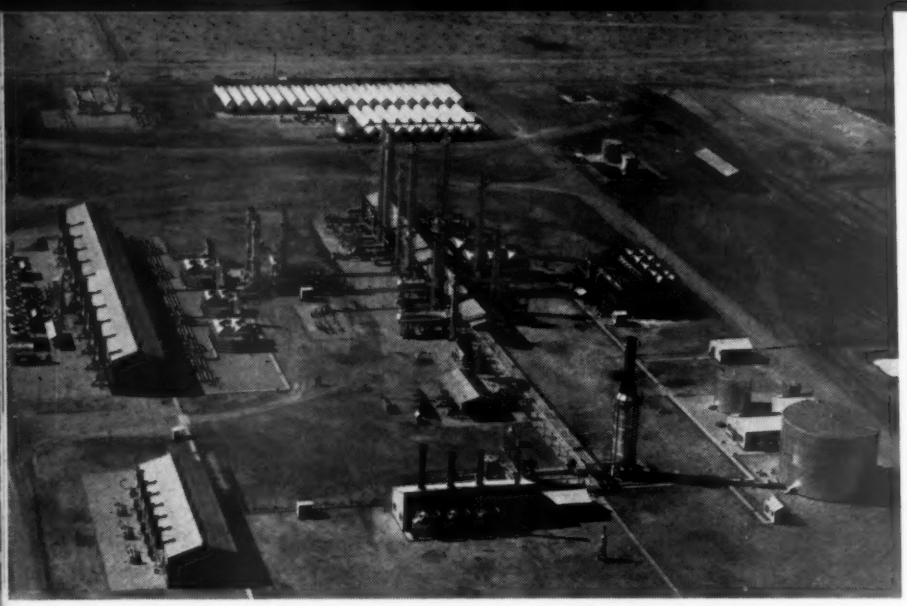
Styrene (unsaturated)

The Complexity of Petroleum

The foregoing description shows the diversity and the extremely large number of possible combinations of carbon and hydrogen atoms that may exist in a molecule. For all practical purposes it may be considered infinite. Therefore, it is not astonishing that relatively few hydrocarbons present in petroleum have been isolated and identified. This is possible only with the hydrocarbons of a fairly simple nature, like those that constitute the lowest boiling portions of crude oil. The complex composition of petroleum also explains the difficulty of employing it as a raw material for manufacturing chemicals. With the exception of the few low-boiling hydrocarbons, the rest of the hydrocarbons are present in crude oil in very small quantities, or have similar boiling points. This makes their separation practically impossible. However, considerable progress has been made in connection with the utilization of the low-boiling hydrocarbons by converting them into valuable by-products or high-grade motor fuels. Commercial processes of this type are new, but represent an important addition to refinery technology. More extended discussion of these new developments will be given in later chapters.

★ *Selected for Merit*

pegasus p



▲ Hawk's-eye view of Magnolia-operated Pegasus gasoline plant. Process area, center; storage in background, power and compressor stations left.

. . . pride of the permian

THE Pegasus natural gasoline plant, 31 miles southwest of Midland, Texas, owned by seven companies and operated by Magnolia Petroleum Company, one of the owners, is a first rate example of the best in gasoline plant design and construction. Processing about 60,000,000 cu ft per day of raw gas, it recovers about 162,000 gal per day of liquid products, including natural gasoline, 45,000 gal; butane, 36,000 gal; propane, 77,000 gal, and drip condensate, 4600 gal.

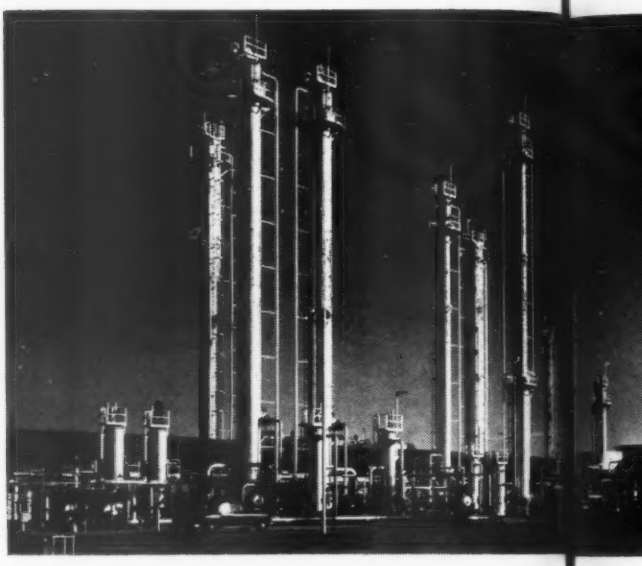
The raw gas is desulfurized before entering the absorber system by means of an amine unit. The strippd gas is dehydrated via the glycol method before going to pipe lines. Main process equipment includes two high-pressure absorbers and on reabsorber. Blowndown water is disposed of in surface evaporation pits.

One outstanding feature is the wide use of atmospheric cooler units for almost all cooling purposes. In fact, this coolant is used so effectively that the daily "ration" of makeup water for *all* purposes including boiler water, is only 38 gal.

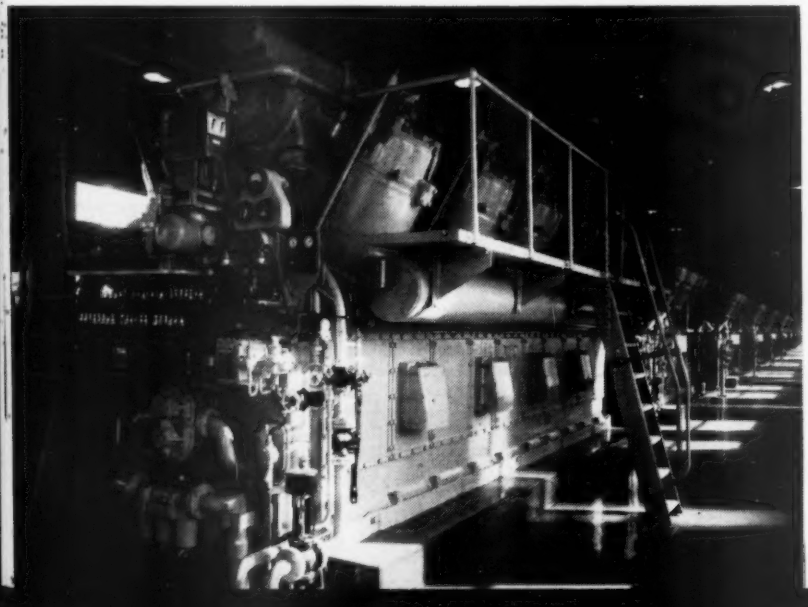
The plant was designed by Magnolia and built by Hudson Engineering Company.

Owners of the plant include Aurora Gasoline Company, Gustave Ring, M. T. Halbouty, Magnolia Petroleum Company, Republic Natural Gas Company, Sharples Oil Corporation, and Spartan Drilling Company.

▼ Symmetrical assembly of units in major process area with absorbers left, reabsorbers and still center, and fractionators in background.



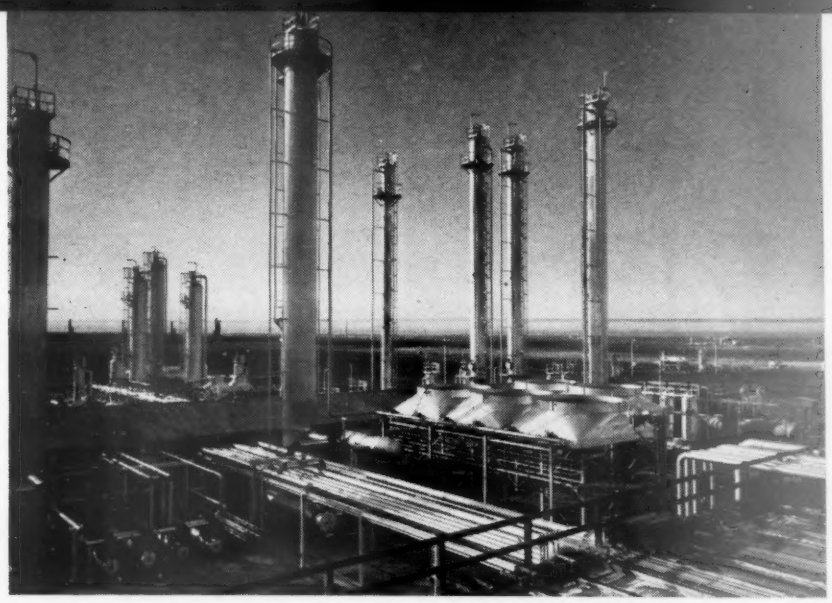
▲ The "heart of the process system," the absorbers are the tall columns in center, with gas dehydrator columns at left.



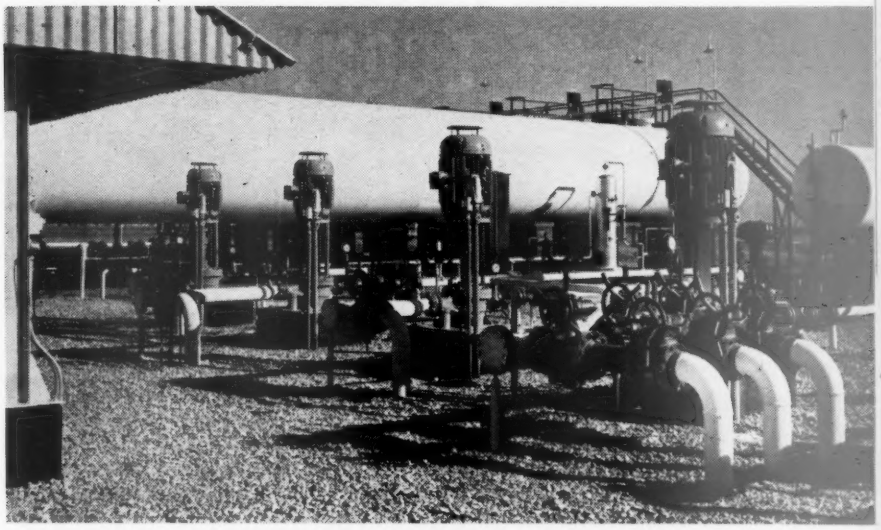
◀ Battery of gas-engine-driven compressors handles all gas coming to the plant.

XUM

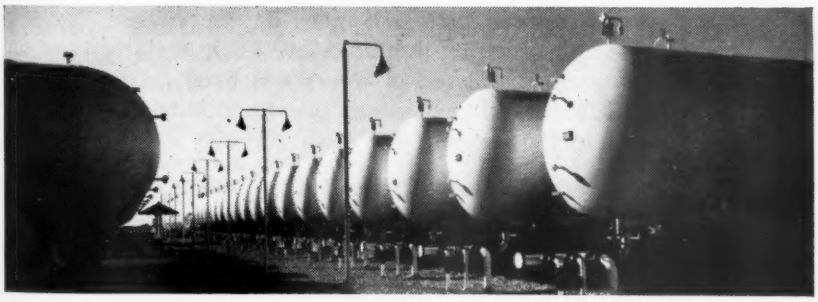
plant



▲ Absorbers, reabsorbers, pump shed, and fractionator columns.

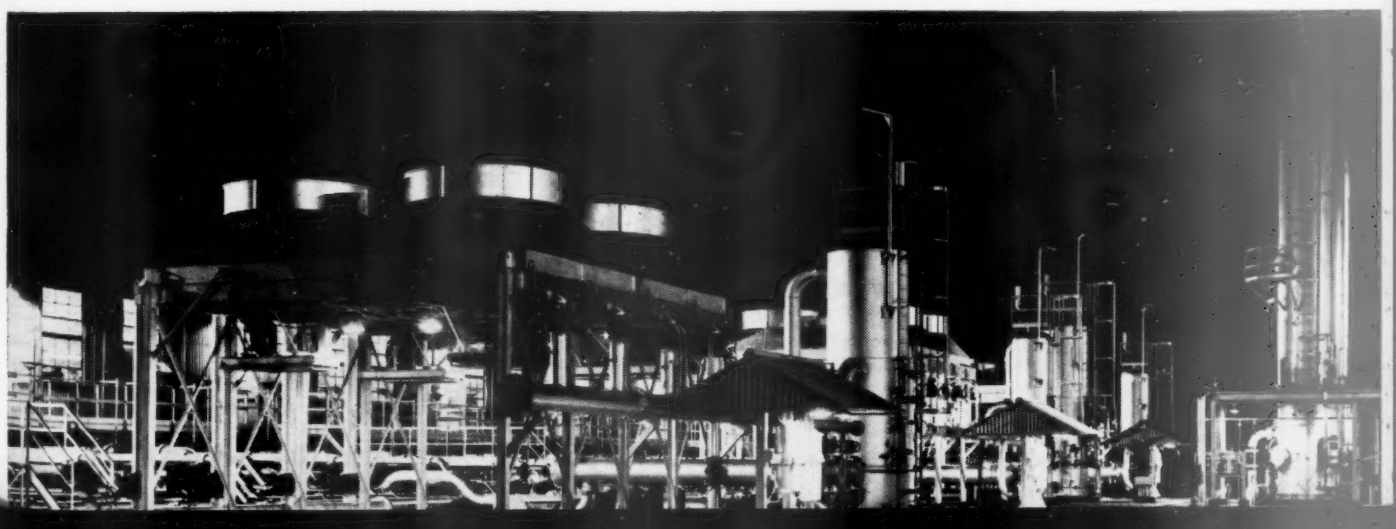


▲ These process load-out pumps handle all the liquid recovered by the plant, sending some products as far as 18½ miles away to loading racks.



◀ These heavy "bullets" store liquid products; natural gasoline at right, propane at left, and butane in the center group of tanks.

In this semi-desert land, the atmospheric coolers may be considered the crucial division of the process system. This picture ▼ was taken at night.



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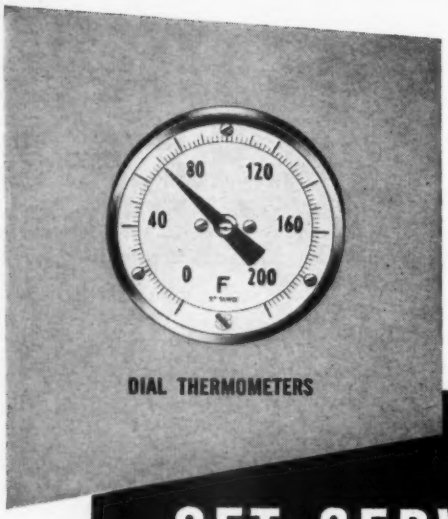
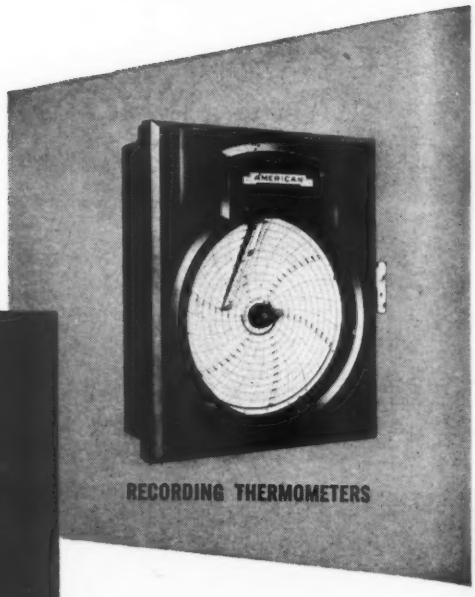


DIAL THERMOMETERS



RECORDING THERMOMETERS

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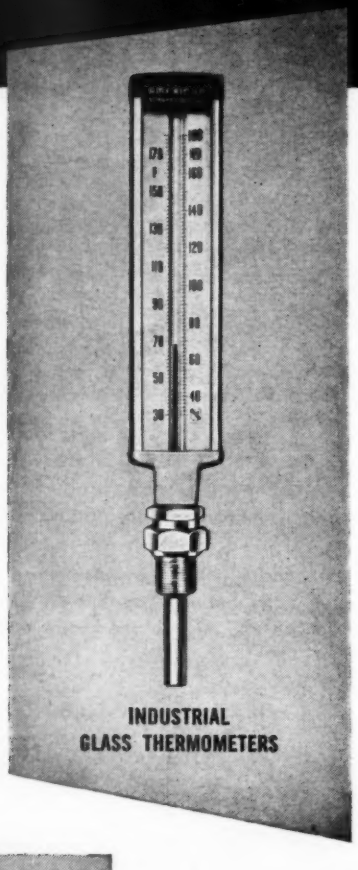

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Bottom-of-the-barrel processing boosts gasoline yield, increases coke only slightly

NEW CATCRACKING PROCESS SOLVES RESIDUUM PROBLEMS

J. C. Dart;
G. A. Mills;
A. G. Oblad,
and C. C. Peavy*

DEMAND for gasoline and light distillate fuels has been increasing more rapidly in recent years than demand for heavy residual fuels, with the result that the disposal of heavy fuels on a profitable basis has been, in many places, a burden to the refiner. Considerable effort, therefore, has been devoted to the development of new refinery processing techniques that provide greater flexibility with respect to product demand as well as product quality.

Houdry Process Corporation has developed Houdresid catalytic cracking to meet these needs. Houdresid is a new refinery-proved, continuous moving bed catalytic cracking process for converting crude residua to high quality distillate products.

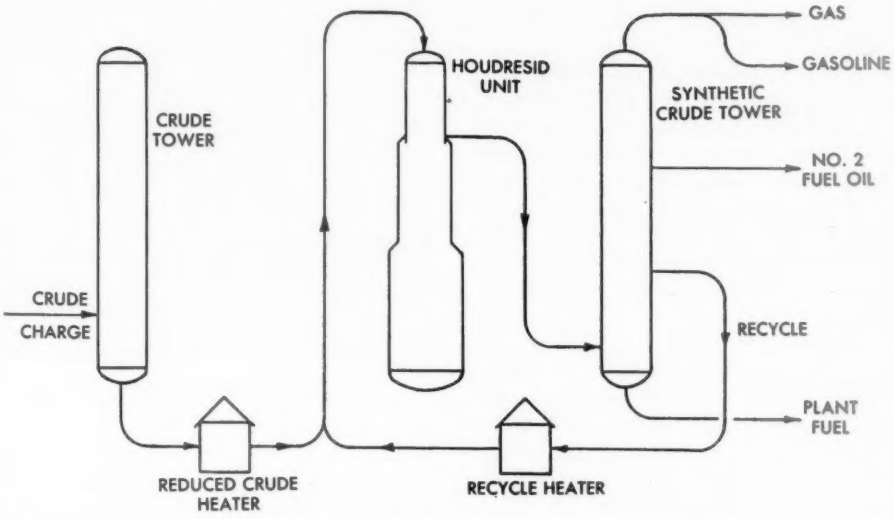
Houdresid cracking utilizes either natural or synthetic catalysts, and the equipment required is similar in many respects to that employed in Houdriflow catalytic cracking.

High yields of gasoline, with octane ratings typical of gas oil catalytic cracking, are produced from residuum cuts ranging from crude tower bottoms to vacuum bottoms. Novel process features eliminate the adverse effects on product selectivity heretofore resulting when heavy metals are present in the feed. In addition, residua high in sulfur or nitrogen may be charged. Houdresid, therefore, gives refiners much greater flexibility in the kind of crude that can be run.

Using a long range residuum, Houdresid has been in commercial operation for over a year. In addition, it has been studied extensively in the laboratory. This paper describes the process, and presents pertinent results from both the commercial operation and the pilot plant studies on a variety of charge stocks.

*Houdry Process Corp.

FIG. 1. Simplified flow diagram of Houdresid operations.



Commercial Application of Houdresid

Description of the Operation. The commercial demonstration was carried out at the Sarnia, Ontario, Canada, refinery of the Sun Oil Company, Ltd. The operation began on March 14, 1954, and has been conducted with outstanding success since that time. A simplified flow diagram of the Houdresid process now in operation at Sarnia is presented in Fig. 1. A photograph of the Sarnia Houdresid system is shown as Fig. 2.

The total crude is fractionated to produce gas, gasoline, naphtha, kerosine, No. 2 fuel with an ASTM 90 per-cent-point no greater than 600 F and bottoms. Reduced crude from this distillation, representing about 45 to 50 per cent of the crude, constitutes virgin feed to the Houdresid unit.

Synthetic crude from the Houdresid reactor is fractionated to produce gas, gasoline, No. 2 fuel, heavy gas oil, and a small bottoms cut which is consumed as refinery fuel. Heavy recycle gas oil is cracked to extinction.

The process and mechanical design of the Houdresid unit are based on information and equipment developed in the well established Houdriflow gas oil cracking process. Oil, catalyst, and air flows are similar to those in a Houdriflow unit previously described.[1,2]

Process Results. Inspection of the reduced crude from mixed Louisiana, East Texas, and Mid-Continent crudes which is charged to the Sarnia Houdresid operation is presented in Table 1. The results of typical yield surveys are presented in Table 2.

Conversion ranged from 65 to 70 volume per cent, variation being con-

TABLE 1. Inspection of charge to the Sarnia Houdresid operation.

Charge	Reduced crude from mixed Mid-Continent, Texas and Louisiana Crudes
Gravity, °API	26.9
Distillation, V. A., °F.	
Initial B. P.	650
50%	804
E. P.	1066
Recovery, %	84.0
Sulfur, wt %	0.47
Ramsbottom Carbon, wt %	3.0
Nickel as metal, ppm	4.6
Vanadium as metal, ppm	6.1
Iron as metal, ppm	9.4

sistent with changes in throughput, recycle ratio, space rate, catalyst-to-oil ratio, and temperature during the residuum cracking operation.

The C_5+gasoline yields varied from about 48 to 53 volume per cent, and coke yields varied from approximately 5.9 to 8.2 weight per cent.

Considering changes in processing conditions, correlation of these data and data from other surveys indicates no significant shift in product distribution with time. Thus, the heavy metal contaminants that accumulated on the catalyst had no effect on the Houdresid process results.

Further evidence of this is demonstrated by the hydrogen yield expressed as standard cubic feet per barrel of residuum converted. Hydrogen production has remained essentially constant throughout the Houdresid run. In conventional gas oil cracking, metal contamination of the catlyst is accompanied by a pronounced increase in hydrogen production.

Unsaturation in the C_4 cut from the commercial operation has been consistently greater than 60 per cent, and C_3 cut unsaturation has been more than 75 per cent. These data are typical of Houdresid process results, and represent a substantial increase in saturation of these cuts over that obtained from gas oil catalytic cracking. Therefore, the Houdresid process provides a greater potential polymer gasoline yield from polymerization of the C_3 and C_4 cuts.

The yields and octane ratings of the C_5+ gasoline, without and with polymer gasoline and the latter blended to 10 lb. Rvp are presented in Table 3. The yields of 10 lb. Rvp gasolines (including calculated cat poly gasoline from polymerization of Houdresid C_3 and C_4 olefins) range from 63 to 66 volume per cent of long range residuum and F-1 clear octanes range from 91 to 95.

Catalyst Resistance to Contamination. From March 14, 1954, to November 16, 1954, 802,000 bbl of residuum produced from 1,663,000 bbl of crude oil were changed to the Houdresid process at Sarnia. The history of metals accumulation on the catalyst and its effect on activity, as determined by the CAT-A laboratory test[3] during this period, are shown graphically in Fig. 3.

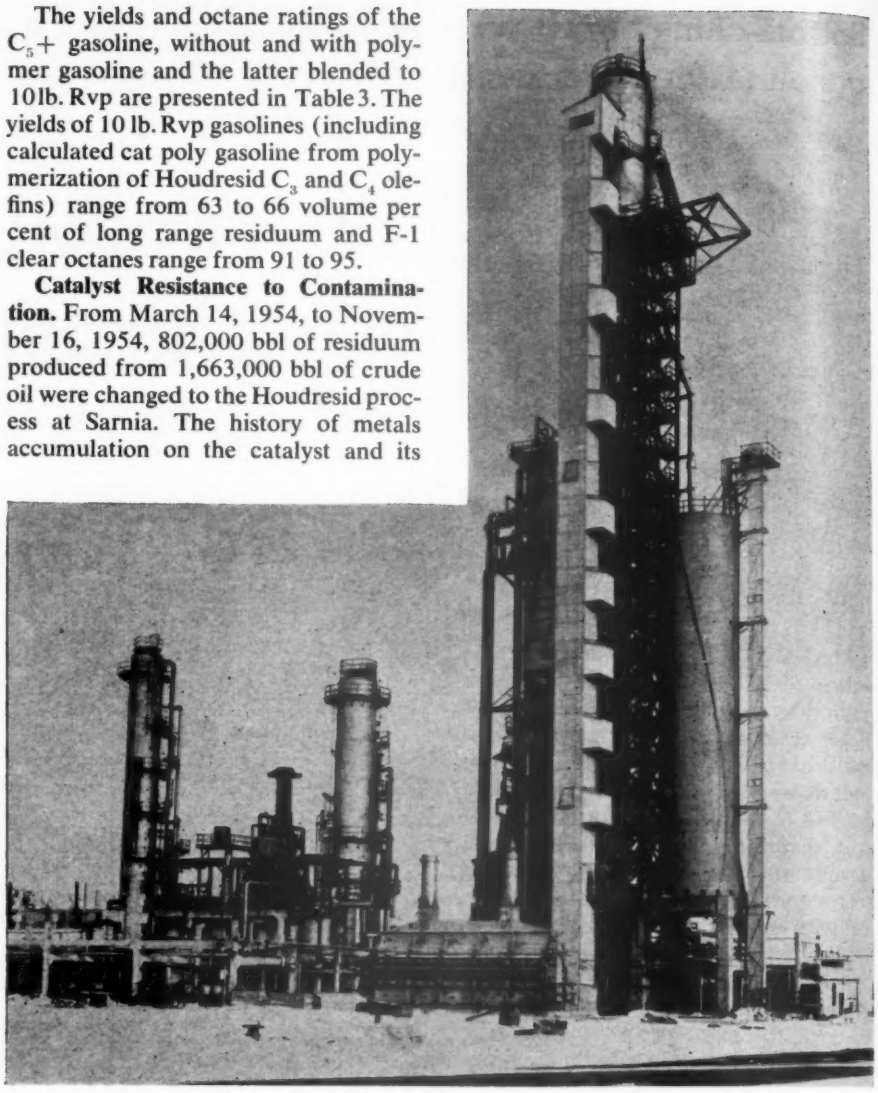


FIG. 2. Houdresid Unit at Sun Oil Co. refinery, Sarnia, Ontario.

TABLE 3. Houdresid C_5+ gasoline yields, before and after polymer gasoline blending.

Survey date	3-19-54	5-27-54	11-16-54	2-3-55
Plant data—Debutanized gaso., Vol %	48.5	50.1	52.7	51.6
F-1 Clear octane	93.0	90.7	88.4	91.6
Calculated debutanized gaso. plus polymer gasoline, Vol %	58.6	58.6	61.2	60.3
F-1 clear octane	94.7	92.5	90.3	93.2
Calculated Total 10 lb. Rvp gaso., Vol %	62.8	63.4	65.9	64.3
F-1 clear octane	95.2	93.8	91.2	93.7

TABLE 2. Sarnia Houdresid survey results.

Date	3-19-54	5-27-54	11-16-54	2-3-55
Crude, BPSD	10,180	12,360	12,111	12,800
Cracking Temperatures, °F	945	940	910	935
Houdresid charge				
Reduced crude, BPSD	5,920	5,453	5,453	6,410
Recycle, BPSD	2,344	3,372	4,455	3,599
Total, BPSD	7,364	8,825	9,944	10,009
Yields, (Based on fresh feed)				
Conversion, Vol %	67.6	65.3	69.8	67.6
Debut. gaso., 385 F at 90 %, vol %	48.5	50.1	52.7	51.6
#2 fuel, Vol %	25.4	22.1		23.0
#5 fuel, Vol %	7.0	12.6	30.2	9.4
C_4 cut, Vol %	14.8	12.4	12.9	13.1
Dry gas, wt %	10.3	8.4	7.3	7.9
Coke, wt %	7.1	5.9	8.2	5.9
Cracking efficiency, Vol % gasoline x 100 / Vol % conversion	71.7	76.7	75.5	76.3
Hydrogen, SCF/Bbl of residuum converted	129	147	108	138
Inspection of C_5+ gasoline				
Octane number F-1 clear	93.0	90.7	88.4	91.6
F-2 clear	79.9	79.1	—	79.1
Rvp	6.0	5.1	—	6.2
Sulfur, wt %	0.08	0.08	—	0.08

The CAT-A activity of the natural catalyst was 26 prior to residuum operation, and appears to have stabilized at 23.5. The gas and coke yields remained normal for these activity levels. Iron content of the catalyst increased from 1.0 to about 1.5 weight per cent and has remained at this value.

Total nickel-plus-vanadium content of the catalyst was about 200 ppm before Houdresid operation commenced. This represents the approximate tolerable limit of contamination in gas oil catalyst cracking.[4] Contamination above this limit in conventional

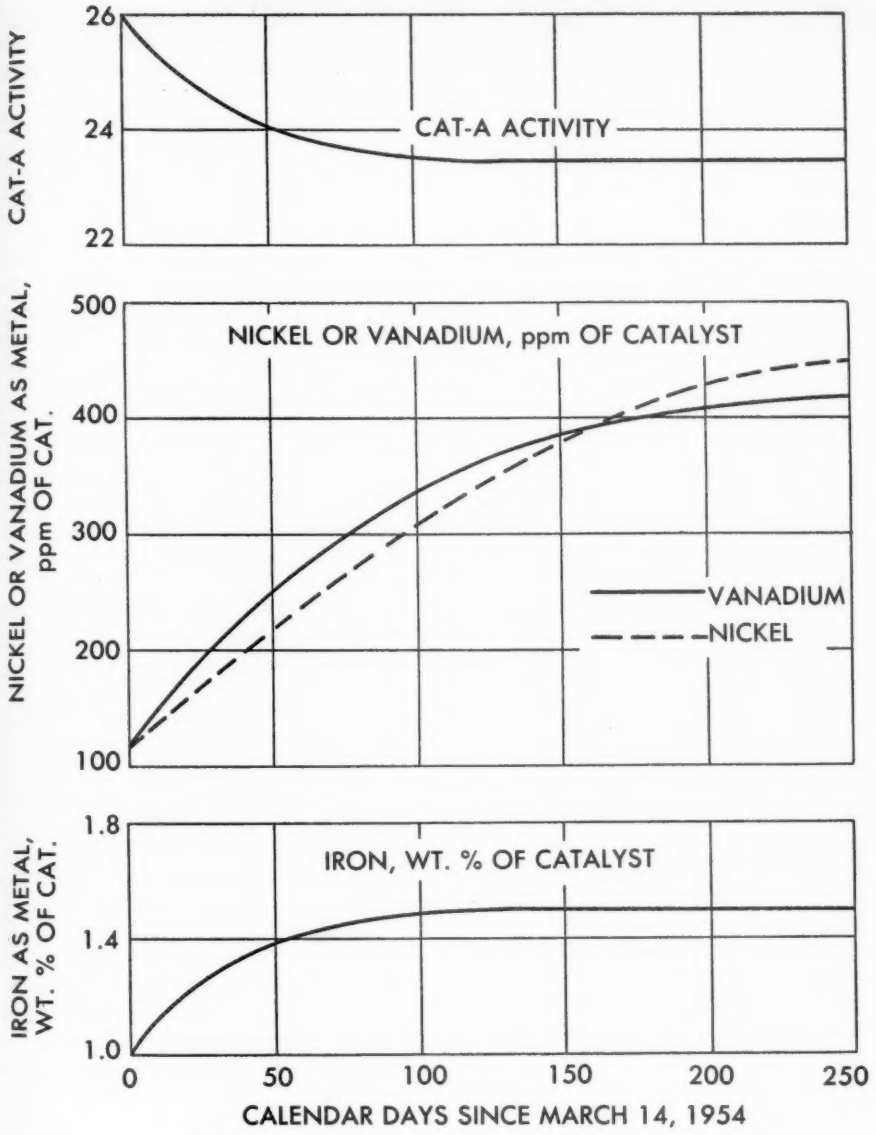


FIG. 3. History of metals accumulation of Houdresid catalyst and its effect on catalyst efficiency.

catalytic cracking markedly influences cracking selectivity, so that high yields of light gases and coke, and low yields of gasoline, are the result of ordinary processing. By November 16, 1954, after eight months of Houdresid operation, the total nickel-plus-vanadium content of the catalyst had reached 870 ppm. It is extremely significant, therefore, that in Houdresid catalytic processing, these high concentrations of contaminants had no effect on product distribution or quality. In effect, the iron originally present in the natural catalyst along with the iron, nickel, and vanadium deposited thereon during processing had been rendered inactive.

Catalyst attrition on the Sarnia Houdresid unit averaged 2.5 tons per day (0.4-0.5# catalyst per bbl of reactor charge). The commercial experience has demonstrated that it is not necessary to withdraw catalyst, over and above that required from normal mechanical loss, in order to maintain selectivity and activity.

A salient Houdresid feature that minimizes the effect of metallic contaminants in the charge is the pelleted form of the catalyst. Metal deposition occurs predominantly on the very exterior of the pellet. This deposit, in turn, is most susceptible to removal by the normal gentle grinding action occurring in a moving bed. Substantial amounts of the metal are thus physically removed from the catalyst, and eliminated with the catalyst fines.

By March 21, 1955, more than a year after the new Houdry process was placed in commercial operation, approximately 1,127,000 bbl of reduced crude (produced from about 2,336,000 bbl of crude) had been processed in the Sarnia Houdresid unit. During this period, yields and product quality have remained high and unchanged. Thus, it has been demonstrated by commercial operation for a truly significant period that Houdresid cracking is a feasible and extremely attractive process for producing quality products from reduced crude.

Laboratory Studies

Pilot plant studies have been carried out to establish the various features of the Houdresid process, including a correlation of results of pilot plant and commercial operation.

It has been established thereby that both natural and synthetic catalyst may be used, and that an inexpensive natural catalyst is particularly well-suited to Houdresid.

A wide variety of long and short range residua, particularly those containing high concentrations of contaminants, has been evaluated. Typical results from these stocks, along with data comparing pilot plant and commercial operation, are presented in accompanying tables. The pilot plant used for these studies has been described previously in connection with the development of Houdriflow catalytic cracking.[5,6,7]

Comparison of Commercial and Pilot Plant Results. Pilot unit and Sarnia Houdresid data from equivalent operation are presented in Table 4. The commercial data are from the survey of November 16, 1954, at which time 802,000 bbl of residuum had been processed. In general, the product distributions are in excellent agreement, and demonstrate that the pilot unit data are representative of results from commercial Houdresid operation.

TABLE 4. Comparison of Houdresid pilot plant and commercial results.

	Pilot unit	Commercial unit
Conversion, vol %	70.0	69.8
Dubut. gaso., 385 at 90 % vol %	50.5	52.7
Total gas oil, vol %	30.0	30.2
C_4 cut, vol %	15.2	12.9
Dry gas, wt %	9.8	7.3
Coke, wt %	7.9	8.2
Cracking efficiency: Vol % gasoline x 100 / Vol % conversion	72.2	75.5

Houdresid Processing of Long Range Reduced Crudes. In the general category of long range reduced crudes, the charge stocks studied represent material boiling above virgin No. 2 fuel oil, and range in Ramsbottom carbon content from 2.8 to 4.5 per cent.

Typical results from two of these stocks are presented in Table 5. With these stocks, once-through operation gives reasonably high yields of gasoline. Pilot plant yields here, and in the following tables, do not include potential polymer gasoline. The coke yields are slightly higher, naturally, than would be expected from a clean catalytic gas oil. The liquid recoveries from operation of these stocks are exceedingly high, however.

TABLE 5. Houdresid processing of long range residua.

Charge stock	40% East Texas reduced crude	27.5% South-Central Texas mixed reduced crude
Gravity, °API	23.7	22.7
Sulfur, wt %	0.54	0.52
Nitrogen, wt %	0.17	0.11
Ramsbottom carbon, wt %	4.5	2.8
Nickel as metal, ppm	7.5	7.0
Vanadium as metal, ppm	<2.5	5.0
Yields, % of fresh feed	once-through	once-through
Debut. gaso., vol. %	44.3	40.5
Cat. gas oil, vol. %	39.7	44.1
C_4's, vol. %	13.8	11.0
Dry gas, wt %	7.9	9.5
Coke, wt %	6.9	6.2
Inspections of C_5^+ gasoline		
F-1 Clear octane	91.6	94.1
Sulfur, wt %	0.66	0.11

The yield of C_4 is exceptional from both charge stocks, and the inspections of the gasolines are excellent. The total gas oils produced in these runs have end points in the range of 875 to 900 F. These gas oils are equally suitable for recycling in a Houdresid unit, or as charge to a gas oil cracking unit. As shown later, recycle Houdresid operation results in very attractive yields.

Houdresid Processing of Heavy Residua. Typical results from Houdresid processing of tar separator and heavy vacuum bottoms are shown in Table 6, which presents data on 10.6 per cent tar separator bottoms, a 10 per cent vacuum bottoms and a 4.1 per cent vacuum bottoms from several crude sources.

Processing the 10.6 per cent bottoms from South-Central Texas mixed crude results in excellent gasoline yields, with reasonable coke production. The gasoline F-1 clear octane from processing this charge stock is 93.4.

With both the 10 per cent mixed Mid-Continent, Texas and Louisiana vacuum bottoms and the 4.1 per cent South-Central Texas mixed crude vacuum bottoms, good gasoline yields at octanes in the range of 90 are obtained. The coke yields are higher, as would be expected, than that resulting from conventional gas oil catalytic cracking. However, the Ramsbottom carbon content of these charge stocks is extremely high. With charge stocks of high Ramsbottom carbon content, no difficulty was encountered in operation of the unit.

Houdresid Processing of Residua Containing High Metal Concentration. Residua having high sulfur, nitrogen, and metal content were investigated as potential Houdresid feed stocks. Typical pilot plant results obtained from four such stocks are given in Table 7. All of these stocks contain between 3 and 5 per cent sulfur, and from 100 to 1100 ppm of heavy metals. The nitrogen contents range from 0.3 to 0.7 weight per cent.

Once-through operation with these charge stocks results in debutanized gasoline yields of approximately 29 to 37 per cent at conversion levels in the range of 50 to 65 per cent. Coke yields vary from 15 to 22 weight per cent.

Recycle operation, as shown for heavy Wyoming reduced crude, results in a substantial increase in gasoline yield, the increase amounting to 17 volume per cent of charge, with only small increase in gas and coke yields.

Even with such highly contaminated charge stocks, gasoline octanes in the range of 90 to 92 F-1 clear are obtained. Both Ordonez and Boscan topped crude yielded approximately 2 weight per cent hydrogen sulfide, which is included in the dry gas yield.

TABLE 6. Houdresid processing of heavy residua.

Charge stock	10% Mixed Mid-Continent, Texas and Louisiana reduced crude	10.6 South-Central Texas mixed reduced crude	4.1% South-Central Texas mixed reduced crude
Gravity, °API	12.6	17.7	12.7
Sulfur, wt %	0.91	0.72	1.02
Nitrogen, wt %	—	0.20	0.36
Ramsbottom carbon, wt %	12.4	5.3	14.0
Nickel as metal, ppm	18.8	18.2	47
Vanadium as metal, ppm	7.4	13.0	33
Yields, % of fresh feed	once-through	once-through	once-through
Debut, gaso., vol %	40.1	42.6	40.4
Cat. gas oil, vol %	40.2	37.0	27.1
C_4's vol %	10.4	13.1	15.6
Dry gas, wt %	7.3	11.6	13.5
Coke, wt %	16.3	8.5	17.6
Inspections of C_5^+ gasoline			
F-1 clear octane	89.3	93.4	90.7

TABLE 7. Houdresid processing of residua containing high contaminant concentrations.

Charge stock	Ordonez topped crude	Boscan topped crude	Heavy Wyoming reduced crude		Kuwait vac. bottoms
Gravity, °API	12.3	7.7	12.2		9.7
Sulfur, wt %	3.72	4.96	3.48		5.03
Nitrogen, wt %	0.42	0.70	0.38		0.33
Ramsbottom carbon, wt %	13.3	10.4	11.8		16.7
Nickel as metal, ppm	44	74	37		42
Vanadium as metal, ppm	242	1090	76		98
Yields, % of fresh feed	once-through	once-through	once-through	recycle	once-through
Debut, gaso., vol %	29.2	33.9	31.1	48.2	37.1
Cat. gas oil, vol %	49.6	43.8	44.5	26.1	34.6
C_4's vol %	7.0	7.0	10.6	10.1	9.6
Dry gas, wt %	9.8	8.8	10.4	12.3	9.7
Coke, wt %	15.1	18.6	15.2	18.2	22.1
Inspections of C_5^+ gasoline					
F-1 clear octane	90.3	92.1	91.8	93.0	88.9

Conclusions

1. A new process, Houdresid catalytic cracking, has been developed by Houdry Process Corporation. This process enables the refiner to crack crude residua catalytically. The process is economical and is particularly well adapted to the use of relatively inexpensive natural catalysts.

2. The Houdresid process has been proved in commercial operation for over a year. Commercial results are in agreement with pilot plant results and demonstrate that the problem of heavy contamination in catalytic cracking has been successfully solved by the Houdresid process. Commercial data from Houdresid operations confirm the fact that attractive product distributions and high quality products result from processing residua by the Houdresid process.

3. Pilot plant data from Houdresid operation demonstrate that efficient conversion of a wide variety of residua, including those high in sulfur, nitrogen and metal contaminants, is possible. Recycle operation with even the heaviest of residuum fractions provides increased gasoline yield at only moderate increase in coke deposition.

Considering its many outstanding advantages, including the ability to process the "bottom of the barrel", Houdresid should find widespread application in the petroleum industry.

At the present time several units for the processing of reduced crude are in various stages of design.

Houdresid catalytic cracking is now available for general licensing to the refining industry by Houdry Process Corporation.

Acknowledgment

The cooperation of Sun Oil Company in establishing the commercial feasibility of Houdresid in the Sarnia refinery is gratefully acknowledged, as are the contributions of its technical staff and management.

Acknowledgment is also made of Houdry personnel contributions made by J. W. Schall, D. H. Stevenson, J. B. Maerker, and F. Walser in pilot plant and commercial development, and R. K. Smith, J. H. Krause, T. H. Milliken, and H. Heinemann in research leading to this new process.

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* * *

Second part of three articles

plastics on parade

(Courtesy Watson-Stillman Company).

▲ FIG. 1. Fabricating plastics can be costly, as witness the size and complexity of this injection molding machine

Phenolics open new chapter for synthetic resins; urea-formaldehyde introduces new aspect

George Barsky
Barsky & Strauss, Inc., New York

PHENOLICS were the first truly synthetic plastics.* That phenol would react with formaldehyde was known for many years before the first attempts were made to utilize products of the reaction as substitutes for shellac, then employed for coatings and for fabricated plastics such as phonograph records. Commerical exploitation of the reaction resulted from the work of three groups of investigators under Bakeland, Aylesworth, and Redman. Bakeland himself made the largest chemical contribution and was responsible for the development of the heat and pressure molding technique.

The new phenol-formaldehyde compositions exhibited very desirable electrical properties and filled the need created by the expanding electrical industry. The production of picric acid during World War I provided large manufacturing facilities for phenol and facilitated the expansion of the phenolic plastics industry. The development of radio during the twenties contributed an additional demand, and uses for the new material multiplied. Today phenolic molding and laminating products are standard materials.

Phenol molding and laminated products possess unusual combinations of properties. They are easily fabricated to intricate shapes, allow molding around metallic inserts, and require no plasticizers. The finished materials are rigid even when hot because of reactions that take place during curing. They are inert to ordinary reagents except alkalis and are age-resistant. Mechanical, electrical, and heat resistant properties can be accentuated by changes in the composition as required. Limitations on the size of the molded piece have gradually been extended. Combinations with paper, canvas, and other fabrics allow larger sections to be made and also provide improved shock resistance.

Phenolic resins have also proved themselves of value in coating compositions, where they are usually blended with natural products such as chinawood or linseed oil. One handicap of the phenolics is their dark color and tendency to further darken with age. Another is a characteristic phenolic odor which prohibits their extensive use in food containers, for example.

The phenolics have been on the market for almost 50 years. They have been responsible for many advances in fabrication and have a greater variety of outlets than any other materials. Other than for their normal growth, their increased consumption depends on the development of new uses, new fabricating techniques, or new combina-

*See Part I, Page C-37, *The Petroleum Engineer*, May, 1955.

EXCLUSIVE

XUM

tions. One new and promising use is in shell molding technique for foundries.

Phenolic plastics are manufactured by reacting phenol and formaldehyde in the presence of a catalyst in steel kettles equipped for reflux and distillation. The reaction is exothermic and the temperature is controlled by water circulating through a jacket. Water is evaporated from the condensation product under vacuum and the hot liquid resin discharged onto trays and allowed to solidify. To make molding powder, the solid resin is broken, ground with catalyst, mold lubricant, filler (wood flour, asbestos, or mica) and coloring matter. The complete mixture may be further compounded on steam-heated rolls into sheets which are then ground to powder.

For laminating purposes, the resin is made similarly and dissolved in alcohol; in this form it is used to impregnate paper, cloth, etc. For plywood adhesive and condensation product may be used without concentration by evaporation. Stability is poor and, if the material is to be stored, refrigeration is required. The dihydric phenol, resorcinol, is used for some special adhesive purposes.

Other variations of phenolic resins are made for special purposes. For varnish use, substituted phenols are required in order to impart solubility in drying oils. The cast phenolics are made by modification of the phenol-formaldehyde ratio and the use of glycerine and lactic acid. The thick syrup obtained by vacuum evaporation is poured into molds and cured by heating in ovens for several days. Further fabrication of cast phenolics is by cutting and machining (Fig. 1).

Introducing Color

Urea-Formaldehyde and Melamine-Formaldehyde. Urea-formaldehyde materials were introduced in the late 1920's when urea became available at a low price because of the expansion of the nitrogen fixation industry. Like the phenolics, the base resin is thermosetting but, unlike the phenolics, it is colorless and may be pigmented to almost any color, including pastel shades. The striking novelty of color opened up hitherto unsuspected decorative possibilities for plastics. Urea-formaldehyde molded products have poorer dimensional stability than the phenolics and the temperature to which they can be exposed without marked change is much lower. They are much more water-sensitive.

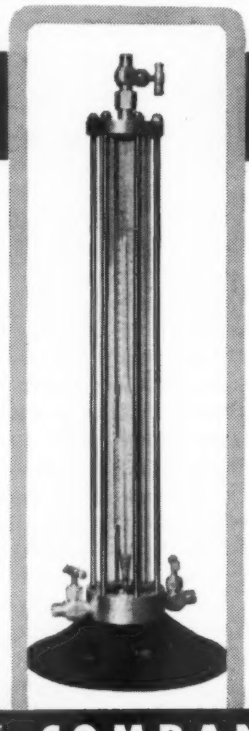
Like the phenolics, urea-formaldehyde materials are available in the form of molding powders, laminating resins for paper, fabric and plywood, and as resins for coating use. The latter is an alcohol-modified product. Urea-formaldehyde resins are extensively used for the crush-proofing of textiles and to improve the wet strength of paper. The methods of fabrication of molding and laminating materials are similar to those for the phenolics.

The manufacture of urea molding plastics is a comparatively simple operation, but it requires stainless steel or aluminum equipment to avoid discoloration of light-colored products. Urea and formaldehyde are condensed under ordinary temperatures and pressures with the addition of catalyst. The resulting solution is mixed with paper pulp, or other filler, dried with hot air under controlled conditions, and ground. Coloring pigments and molding accelerator are then added, and a final grinding operation takes place in brine-cooled ball mills. In dark colors, where contamination is not a factor, urea-formaldehyde molding powder is the cheapest of all molding plastics.

Laminating solutions and adhesives are made by condensation that may be followed by vacuum concentration. Spray-dried solids are also available. Generally, in the use of adhesives or laminating materials, small amounts of acids or acid-generating catalysts are added to cause the resin to set.

Resins for organic coating solutions

PRESSURE HYDROMETER JAR



For obtaining specific gravity of liquefied petroleum gases, such as propane and butane, which under normal atmospheric pressure would evaporate into a gaseous form. Jar withstands operating pressures of 200 psi at normal temperatures. Equipment consist of clear lucite tube, aluminum end caps held by tie-rods and a conical base. Three needle valves allow entry of the sample and adjustment of the liquid level.

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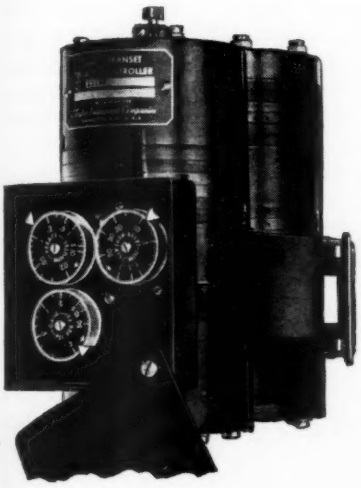
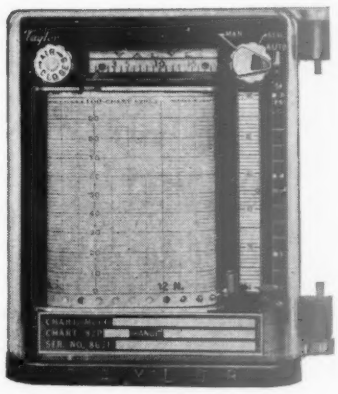


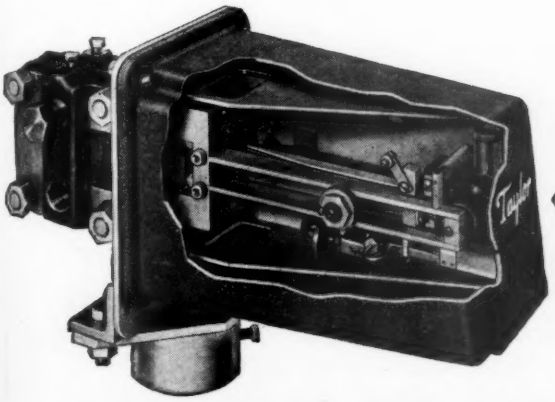
CONTROLLERS

Design and flexibility of neoprene-impregnated diaphragms makes for strength and long life. Can be used on pulsating flows without deteriorating, and are impervious to oil vapors often present in air systems. Simple circuit reduces number of possible trouble points, and force-balance action means minimum of moving parts. Large volume relay valve reduces chances of plugging. Unique nozzle-baffle arrangement is not as susceptible to damage as in other controllers. Built in cut-off relay permits locating instruments behind board or in the field with no change in interchangeability of recorders. Only two adjustments are ever needed for maintenance—and plug-in feature means minimum time off automatic control.



RECEIVERS

Ruggedly housed bellows in receiver units protects it from external damage. Continuous bleed from the reducing valve keeps it purged—free from dust and dirt. Many have been in service over four years without requiring calibration to zero. Units are easy to get at for service, no matter how close on the board, because they can be unplugged. Plug-in feature also means that indicators can be replaced by recorders for analyzing trouble. Removable chart drive is another aid to establishing process problems.



TRANSMITTERS

Both temperature and flow transmitters are ruggedly housed. Located at the point of measurement, they are out of the way of possible damage. Quick, simple range-change features mean minimum maintenance time for changes in product or seasonal demand. Force-balance construction—no seal pots. Follows flows quickly because of low volumetric displacement. Self draining and venting.

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are made by condensing urea and formaldehyde in a different molar ratio than for molding products. The condensate is alkylated by boiling with a selected alcohol; the water of the solution is displaced first by the alcohol and finally by a hydrocarbon solvent.

Melamine-formaldehyde resins are similar to the urea-formaldehydes but have improved moisture resistance and dimensional stability. Molding compounds with mineral filler are superior to the phenolics in arc-resistance. Melamine plastics are being used to an increasing extent in tableware. Their light weight and superior shock resistance give them advantages over chinaware but their susceptibility to coffee stain and their poor scratch-resistance still are major defects.

The principal handicap to growth of the melamine plastics is the high cost of melamine; the latter is produced from calcium cyanamide by a multistep process requiring high pressure. Melamine, however, might be produced from urea and ammonia; in that event its cost would be greatly reduced and melamine plastics would replace the ureas and cut into the phenolics.

Revolutionary Coating Materials

Alkyds. The development of Bakelite stimulated other investigators to match the properties of this first plastic. General Electric researchers took up the observations of Watson Smith on the glycerol-polybasic acid resins. At first, they tried to prepare moldable resins similar to the phenolics but without success. By modifying glycerol phthalate with fatty acids, they developed products that later were useful constituents, of nitrocellulose lacquers. Subsequently, glycerol-phthalate was modified with drying oil fatty acids to give a composition that becomes hard on exposure to air.

These alkyd resins are extensively used in coating compositions because of their superior durability and rapid drying. Their properties vary depending on whether or not the fatty acid is oxidizing, on the proportion of fatty acid used, on the particluar dibasic acid, on the particular polyhydric alcohol (glycerol, glycol, pentaerithrytol, or mixtures), and on additional modifying agents that may be added, such as rosin, phenolic resins, styrene, and silicones.

The use of alkyd resins in surface coatings has increased greatly since the twenties. They now replace lacquer in automobile finishing; they have been adapted to a wide variety of air-drying and baking finishes, in latex emulsion paints, and in the special corrosion-proofing vinyl finishes.

The process of manufacturing alkyds is comparatively simple. The ingredients, for example, phthalic anhydride, glycerol and linseed fatty acids, are heated to reaction temperature in stainless steel or aluminum kettles. Usually a blanket of inert gas is used to exclude air. Straight esterfication takes place with the evolution of water. The final product is discharged into containers or into a thinning kettle where solvent is added. Since the glycerides are cheaper than the equivalent of fatty acid and glycerine, it is common practice to use the neutral glycerides. By heating the glyceride with additional glycerine, a mono- and di-glyceride mixture is formed that then reacts readily with the polybasic acid.

Flexibility

Polyvinyl Chloride. PVC plastics marked a major turning point in the plastics industry. For the first time they made available a synthetic material that was flexible and capable of substitution for textiles. Up to then all synthetic plastic materials were rigid in the finished form. Polyvinyl chloride plastics are more than half chlorine and less than half organic and therefore they may be considered inorganic plastics. As such they antedate silicones by two decades.

The fundamental reaction involved

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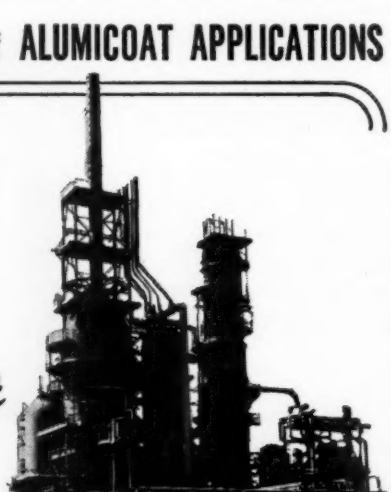

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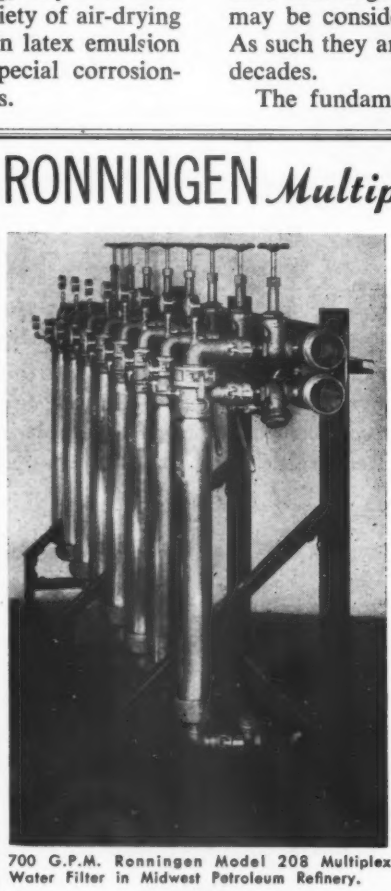

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in the formation of vinyl plastics was observed more than 100 years ago. Variations of this fundamental reaction, polymerization and copolymerization of ethylene derivatives, are the basis for a large part of our synthetic plastics industry. Vinyl, vinylidene, acrylate, allyl, styrene, polyethylene, the synthetic rubbers, and acrylonitrile products are all produced by this polymerization reaction.

Some basic work on vinyl chloride (monochlorethylene) polymers was done by the well known rubber chemist, Ostromislensky. The Goodrich Rubber Company started experimental work in about 1928 and proceeded along the line of adding plasticizers to polyvinyl chloride to permit fabrication. Carbide and Carbon Chemical Company developed copoylmers of chloride and acetate, internally plasticizing the chloride with the acetate.

The acute rubber shortage during the war accelerated the acceptance of polyvinyl chloride products for electrical wire insulation and cable sheathing where they proved to be superior to rubber for many specific applications. Other substitutions, for example in rubberized cloth, resulted in the realization of some of the unusual properties of poylvinyl chloride. After the war, a large market developed for PVC in coated cloth, calendered film, and extruded products.

Unplasticized PVC is a hard, rather brittle material at room temperature, characterized by outstanding resistance to most chemical reagents, water, oil, and oxidation. When plasticizer is added the physical characteristics are greatly changed, depending on the type and amount of plasticizer. It is possible to vary the plastic from a rigid mass to a tough, elastic material, down to a soft, pliable, elastic sheet. One early drawback was the tendency to discolor and become brittle on light- or heat-aging, but stabilizers have been developed which, in small amounts, probably by combining with traces of liberated hydrogen chloride, reduce the rate of decomposition. Stabilizers are responsible to a great extent for the improved durability of PVC and of its increased acceptance for many purposes, as in window or shower curtains, rainwear, lightweight garden hose, etc.

Experience in handling and in compounding PVC has made the fabrication of rigid unplasticized products such as sheet and pipe possible. New techniques for fabricating have also been introduced. The use of plastisols, that is, resin particles dispersed in plasticizer, has permitted the easy application of rather thick layers to fabrics. After the plastisol dope has been spread on the cloth, heat is applied. The PVC swells, absorbs the plasticizer and the mixture becomes homogeneous. This procedure has resulted in the displacement of the old nitrocellulose coating by poylvinyl chloride compositions; the latter are now extensively used for upholstery, luggage, etc. The introduction of a gelling agent in the plasticsol gives a gel that can be formed to a retainable shape when heated. All these variations in fabricating techniques have helped to increase the market for PVC (Fig. 2).

(Courtesy of U. S. Rubber Company).

▲ FIG. 2. Panels of reinforced polyester resin — with aluminum stiffeners — permit higher payloads in trailer-trucks. Naugatuck Chemical's "Vibrin" is manufactured by Fiberglass.

The monomer, vinyl chloride, is made by two methods: The catalytic addition of hydrogen chloride to acetylene; and the removal of hydrogen chloride by thermal cracking of ethylene dichloride. Ethylene dichloride is made from ethylene and chlorine by direct combination; acetylene is made on an increasingly larger scale from natural gas. Polymerization of the monomer is usually effected in water emulsion or suspension with the addition of catalysts. Since the vinyl chloride is low boiling liquid, this operation takes place under pressure. The PVC is recovered by filtration and drying, or by drying the entire emulsion. Compounding of the PVC with plasticizers and stabilizers is similar to the compounding of rubber for which heavy duty mixers are used.

Other Polyvinyl Halides

There are a number of other polyvinyl materials related to PVC; they are less prominent but still interesting because of their unusual physical properties or promise of future growth.

Vinylidene chloride may be considered vinyl chloride with an additional chlorine substituent. Straight polymers are difficult to fabricate but co-polymers with vinyl chloride have had some commercial success. The relatively high vinylidene chloride products are unusually resistant to chemicals, corrosion, and mildew. Pipe, tubing, and monofilaments for screening have had wide acceptance. Small proportions of vinylidene chloride are added as co-polymers to other monomers to produce changes in properties.

Polychlorfluorethylene may be regarded as a completely fluorinated PVC. The plastic is noteworthy for its strength and toughness and its resistance to flame, chemicals, age, and abrasion. It is more difficult to fabricate than PVC but has better chemical

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▲ FIG. 3. Vinyl plastic finds a new use in storm windows made like a window shade. Air pocket between tightly fastened film and window glass provides insulation.

resistance and may be used over a wider temperature range. It is quite expensive and, for this reason, its use has been restricted to such fields as valve packings, special tubing, chemically resistant cloth, etc.

Polytetrafluorethylene is a completely fluorinated product made by polymerization of tetrafluorethylene. The polymer has no true softening point and is very difficult to fabricate; the techniques of powder metallurgy are sometimes resorted to. This fluorine plastic is outstanding in heat resistance, chemical resistance, and low electrical loss. It is used for gaskets and packing in the chemical industry and for some special electrical services.

Polyvinyl Acetate, Alcohol, and Acetal

Polyvinyl acetate is prepared by polymerization of vinyl acetate, often in water emulsion. The monomer, a liquid, is usually made by adding acetylene to acetic acid. PVA itself is colorless. It exhibits flow at room temperature and therefore is not suitable for films, small parts, etc. It is soluble in many organic solvents and usable as coating composition. PVA is used in adhesives, paper coatings, leather, textile, and straw finishes. PVA latices are used as a base for some of the newer water emulsion paints (Fig. 3).

Hydrolysis of PVA gives polyvinyl alcohol, the properties of which vary with the molecular weight of the PVA and the degree of hydrolysis. Extruded and molded polyvinyl alcohols are characterized by resistance to organic solvents. Tubing, gaskets, diaphragms, and packings for use where such resistance is important are made from polyvinyl alcohol. Some grades of polyvinyl alcohol swell in water, and others are even water-soluble. However, by treating the alcohol with aldehydes, acetals that withstand hot water are formed. The butyral compounded with proper plasticizer is extensively used as the inner layer for safety glass of improved low temperature characteristics. The formal is used for wire insulation, particularly magnet wire.

Synthetic fibers from polyvinyl acetals have received considerable attention, particularly in Japan. If the acetic acid that is removed from PVA could be recovered cheaply and re-used to make vinyl acetate, the cost of polyvinyl alcohol would be very low, as the only raw materials would be acetylene and water.

Injection Molding

Polystyrene. Polystyrene is one of the oldest plastic materials known but its commercial production was retarded because of the unavailability of styrene, the monomer, at low prices. At far back as 1911 polystyrene was proposed as a replacement for celluloid, wood, glass, etc., and its excellent electrical properties were recognized. Staudinger, working with syrene (monovinylbenzene) and divinyl benzene, developed some of the modern theories of polymerization and studied the phenomenon of cross-linkage. Although Dow announced the production of clear colorless polystyrene before the war, the monomer was not available in quantity until after the war during which large producing units were built for the synthetic rubber program. The availability of styrene at prices as low as 13 cents per pound resulted in a tremendous impetus to styrene plastics. This situation presents an interesting parallel to that of phenol at the end of World War I, and to the subsequent growth of phenolic plastics.

Polystyrene is well adapted to injection molding, a method of fabrication considerably cheaper than the heat and pressure molding used for the phenolics and ureas. Polystyrene demonstrated the possibilities of this new type of molding technique.

Polystyrene is colorless and transparent and has high tensile strength and excellent dimensional stability. It has a low specific gravity, 1.05, and a smaller weight is therefore required for a given piece than is the case with the phenolics of the ureas. It has unusual electrical properties, particularly low loss at high frequencies, and for this reason, polystyrene insulation is useful in shortwave electronic equipment. Though soluble in aromatic hydrocarbons and chlorinated solvents, it is not affected by alcohol, fats or greases, nor by acids or alkali. Because it retains its impact strength at low temperatures, it has been widely used for refrigerator parts.

A very large number of small devices for household use, toys, housings for small machines, containers of all sorts are made from polystyrene by injection molding. Pieces weighing up to ten pounds are being produced and many colored and mottled effects are possible. Molding cycles vary from 15 seconds to 3 minutes, depending on the mold.

Although ordinary polystyrene has a distortion point of about 170 F and is somewhat brittle, modified polystyrene formulations are available with higher heat distortion temperatures and with improved impact qualities. Some of these are co-polymers and some mixtures of polystyrene with other materials. Co-polymers of styrene and butadiene containing larger proportions

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FIG. 4. Polyethylene is serviceable in refrigerator ice trays; permeable to oxygen and CO but not to H_2O, it serves eminently well for packaging of fresh, living vegetables.

(Courtesy of E. I. du Pont de Nemours, Inc.).

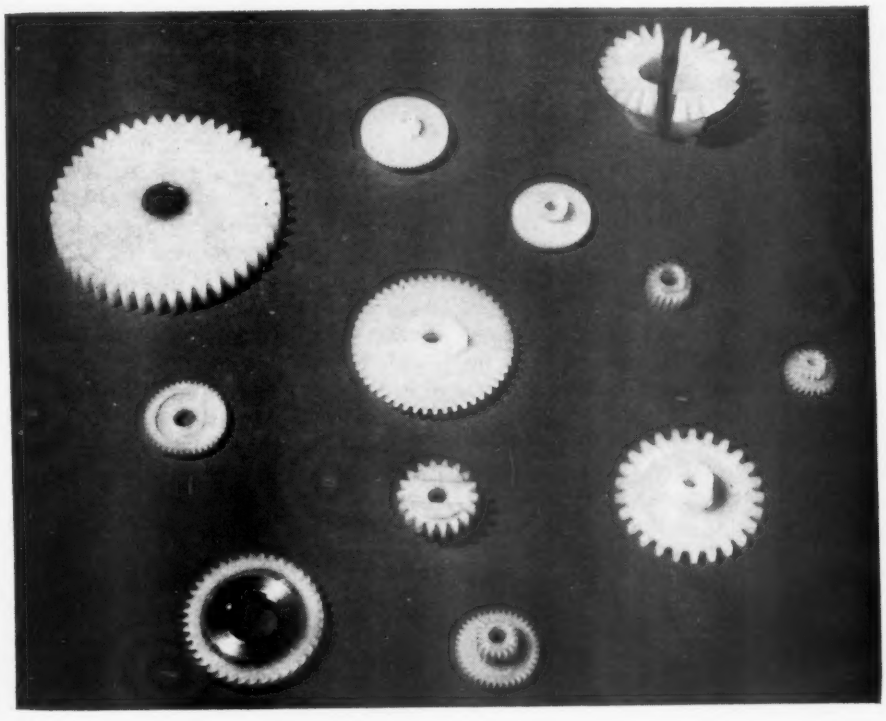

FIG. 5. Nylon lends itself to special plastic applications in tough, abrasion- and chemical-resistant molded gears, bearings, and valve seats.

(Courtesy of E. I. du Pont de Nemours, Inc.).

of styrene than synthetic rubber are used in molding compositions and as a latex in water emulsion paints. Other co-polymers are styrene-divinylbenzene, styrene-acrylonitrile, styrene-isobutylene and styrene-isoprene.

The monomer (styrene) is prepared by reacting ethylene and benzene in the presence of aluminum chloride to form ethyl benzene, which is then dehydrogenated by cracking and purified by distillation. Polymerization may be in bulk or in aqueous suspension. Commercial availability of methyl styrene, prepared by analagous reactions from toluene, has been recently announced.

Divinyl benzene may be used to cross-link the ordinary polystyrene chains and produce an insoluble product. Such a material cannot be injection molded but it can be cast before the final cross-linking action takes place. Styrene itself is used as a cross-linking monomer in many of the polyesters which are described below.

The First Petroplastic

Polyethylene. Not only is polyethylene entirely a petrochemical product, but its discovery was an outgrowth of attempts to polymerize ethylene in order to make liquid hydrocarbons suitable for motor fuel. Thus, it represents the first direct all petrochemical plastic of any consequence. Some petroleum resins resembling the coumarone-indene polymers of coal-tar have been on the market for a number of years, but these are very limited in uses and represent minor by-products.

Polyethylene was developed originally by International Chemicals, Inc., in England. Because of the wartime importance of electrical insulating materials, the information was transmitted to the United States from Britain; Du Pont and Union Carbide became the first American producers. From 9,000,000 lb in 1946, capacity has grown to 135,000,000 lb in 1953. Seven other manufacturers are entering the field and 500,000,000 lb are expected in 1956.

Polyethylene is outstanding for the ease with which it may be fabricated. It can be extruded, blown, calendered and welded. It is remarkably inert chemically. It has a relatively low softening point and is somewhat easily scratched or cut. It has an inherent flexibility with very slight elastomeric properties. In thin sections it is soft and readily deformable but does not have the limpness of plasticized polyvinyl chloride films. In thick sections it is somewhat stiff but not nearly as stiff as unplasticized PVC.

In much of its behavior polyethylene resembles metals though its analagous properties are in a much lower temperature range. It resembles a soft ductile metal; while it has extensibility of 200 per cent or more at rupture, these elongations are not recoverable. Cold drawings, as with many metals, increases the tensile strength. A type of failure, similar to the stress-cracking of brass, occurs with polyethylene if it is subject to excessive strains in contact with some organic liquids that ordinarily are without effect.

Polyethylene is completely nonpolar, chemically stable, and absorbs very little moisture. It therefore has excellent electrical properties including low dielectrical constant and low power factor over a wide range of temperatures; it is of great value as an electrical insulator, particularly for high frequency service. Lead-in wires for television, for example, are insulated with polyethylene. Polyethylene is permeable to oxygen and carbon dioxide but not to water vapor. This combination is of importance in the packaging of certain vegetables.

Low molecular weight grades of polyethylene have poor tensile strength

but are of value as paper impregnants or for improving the characteristics of paraffin wax. It was recently announced that on exposure to radiation polyethylene undergoes cross-linking, the net effect of which is to raise its softening point and convert it to a more rigid material. Other after-treatments of polyethylene have been suggested, but none is yet extensively practiced.

One of the more spectacular uses of polyethylene is in flexible bottles some of which have been made as large as carboys. Polyethylene is used for all sorts of closures, food canisters, drinking cups, refrigerator dishes, etc. Larger and larger pieces are being injection-molded. Film is used in prefabricated lines for a large variety of containers. One outlet that will probably increase with time is for piping to carry cold water (Fig. 4).

Highly purified ethylene is required for the manufacture of polyethylene. The polymerization takes place at around 1000 atmospheres and 200 C. Tubular reactors are used and the design involves problems of heat removal as the reaction is quite exothermic. Conversions of about 20 per cent per pass are obtained and after separation, recovered ethylene is recycled until the impurities build up to a critical value. Some work has been done on a low pressure process, but little information is available.

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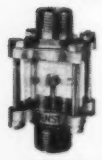

FIG. 29 Cylinder with Impeller

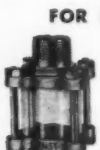

FIG. 17-28 Cylinder

FIG. 215 Flanged

FIG. E-57 Double Window

FIG. 212 Visibility Welding Neck or Screw

FIG. E-811 Flapper

FIG. E-1810 Rotating Wheel Type

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Polyester Plastics. The polyesters are a natural outgrowth of the alkyd resins which chemically can also be considered polyesters. The saturated polyester made from terephthalic acid and ethylene glycol is the material used for Dacron fiber. The same polyester is produced in the form of sheet and of film which have very desirable properties as a backing for photographic emulsions. Commercial production of this material is still in the early stages.

Ordinarily, the term polyester is used to describe condensation products made from dibasic acids, some of which are unsaturated, and from glycols; these condensation products are cross-linked by means of a polymerizable monomer. For example, maleic and phthalic anhydrides may be reacted with di-ethylene glycol to form a viscous liquid. To this polyester there is added some styrene and a polymerization catalyst. The resulting mixture under the influence of heat, is converted to a solid by cross-linking of the linear unsaturated polyester chains through the medium of the very reactive styrene. Other cross-linking agents may be used, such as vinyl acetate, methyl methacrylate, and poly-unsaturated compounds such as di-allyl phthalate.

The temperatures required for cross-linking are relatively low and since no gas is evolved in the reaction, high pressures are not required for final reaction. While products without fillers have been produced, in most cases composite structures are fabricated with glass cloth or mats, or paper or fabric. Relatively large structures may be built out of such combinations, for example, the Corvette automobile body. The rate of production, however, is rather slow at present, as the mechanical devices for making relatively complicated shapes have not yet evolved. Simple shapes, such as large corrugated panels made with fibrous glass mats, have appeared on the market in recent years and are becoming farily well established as an architectural material. Chairs of modernistic design have been made from similar materials. During the war, small boats were made by polyesters and much was expected from these plastics in the immediate post-war era. Until recently polyesters have been somewhat of a disappointment, but they have received a renewed impetus from the development of improved fabricating techniques.

Miscellaneous Plastics

A large number of miscellaneous plastic materials are employed for special purposes because of particular combinations of properties. Among these is polymethyl methacrylate, where superior shock resistance over glass and perfect transparency are the two properties that have brought it prominence. Sheets are standard transparent materials for airplane windows and other transparent enclosures of military planes. Watch and instrument crystals and automobile tail lights are usually made of methyl methacrylate. But one drawback to their extensive use, in automobile and railway glazing, is their poor abrasion resistance.

The acrylate esters, as distinguished from the methacrylates, are much softer. They have, however, found extensive use in coating compositions, textile and leather finishes and the monomers are useful in mixed polymers.

Early in its development, nylon was used for the manufacture of monofilaments for brushes and today practically all of the synthetic bristles in use are made of nylon. Much effort has also been devoted to the possibilities of nylon for special plastic applications. A number of varieties of molding nylon are now available and recognized for some unusual properties: Resiliency, strength, toughness, and low coefficient of friction against many metals. It is recognized as a very superior material for small gears, bearings, and valve seats. The automobile industry is using small nylon parts to an increasing extent. Recent surveys indicate that considerable expansion in the use of molded nylon will take place in the next few years. One of its handicaps is its relatively high price, but this will probably come down as more manufacturers enter the field.

Another class of materials, the silicones, possess unique properties attributable to the presence of silicone in combination. These are not the first organic-inorganic polymers, as they were preceded by polyvinyl chloride. Silicones or polysilanes are heat stable, serviceable at elevated temperatures, relatively resistant to oxidation and aging, water repellant, and have good dielectric properties. As electrical insulating materials they have made it possible to operate equipment at 180 C. This, in turn, allows the operation of a given motor or generator at increased ratings and higher overload, thus reducing first cost. Silicones are also used as water repellants for textiles, as protective coatings, as lubricants, as silicone rubber in gaskets, diaphragms, etc.

(Part III to come).

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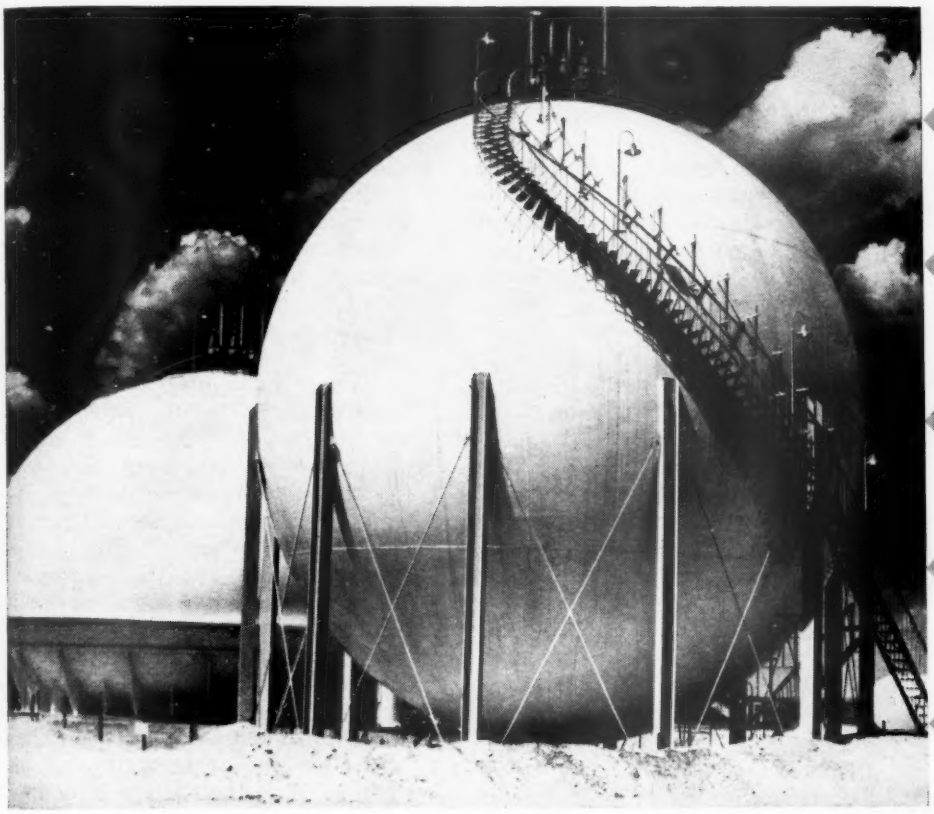

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PETROCHEMICALS, LPG

Are Big Factors

L. O. Crockett, general manager of Gulf Oil Corporation's Chemical division, who discussed at length "The Natural Gasoline Producer's Stake in Chemical Manufacturing."

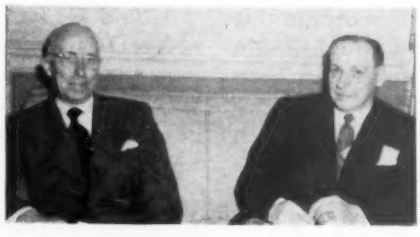
CHEMICAL projects based on sound chemical and economic thinking entered into with awareness ofthe problems involved, blessed with adequate financing, and pursued with tireless determination should have every chance of success," said L. O. Crockett, general manager of the chemicals division of Gulf Oil Corporation, at the 34th annual convention of the Natural Gasoline Association of America in Dallas, Texas.

Here the speaker, one of the outstanding leaders in the refining industry's petrochemical developments summarized the formula for success in this most rapidly expanding of all chemical fields. The petrochemical market demand that the natural gasoline producer may supply varies little from month to month, and offers one potential outlet for the greater production of LPG that the industry faces. The activity of supplying raw material to the chemical industry may be profitable for the natural gasoline maker without involving him in the complexity and heavy financial investment that go with actual chemicals production. Long after natural gas-gasoline hydrocarbons cease to be available in quantities sufficient to cause them to be important in the fuels picture, they will be plentiful enough to be the main source for chemical raw materials. The natural gas operator who has joined experience and know-how in supplying petrochemicals previously will be in better position to continue profitable operation than will be the operator who knows only the fuel market.

The natural gas company will not be alone, nor will it be without competition in supplying the raw materials for chemicals. That company must do considerable research and must build up a staff that can solve some of its own technical problems. Chemical manufacturers require normally a large number of close-cut, well-fractionated raw products. Some idea of the progress in petrochemicals is shown by the fact that in 1953 petrochemicals were produced in the amount of 12,650,000 tons, worth three billion dollars and thus nearly half the value of all chemical production. The rate of growth during the next several years is expected to be nearly as great as it has been during the last 20 years. If this be true, the industry should show a 150 to 170 per cent increase during the next 20 years. Ethylene from natural and refinery gases is one of the largest products, going especially into synthetic ethyl (grain) alcohol and into polyethylene plastic, the so-called squeeze-bottle plastic, and it is estimated that by 1957 we shall use 600,000,000 lb, or 300,000 tons of polyethylene annually. Other applications of ethylene are to make ethylene oxide from which is made ethylene glycol, so-called permanent antifreeze; ethanolamines when combined with ammonia, used in the industry largely to remove sulfur compounds and carbon dioxide from raw gas.

From butanes-and-heavier natural gasoline may be synthesized the various aromatics, largely via catalytic reforming of natural hydrocarbons, yielding benzene, toluene, the xylenes and heavier aromatics of which huge quantities are obtained and used by industry.

Fractionation is becoming an increasingly important factor in natural gas operations, and much attention is being given to improving methods and equipment. The introduction of perfo-



Left to right, R. E. Walker and R. C. Beam, Armco Corporation.

Stan McAnelly, Lone Star Gas Company, and H. R. Legatski, Phillips Petroleum Company.

Left to right, R. H. Westhoff, Stanolind Oil and Gas Company, and Harry Thomas, The Tuloma Corporation.

Joe LaFortune, independent operator of Tulsa, Oklahoma, and H. W. Ferguson, Refining vice president of Humble Oil and Refining Company.

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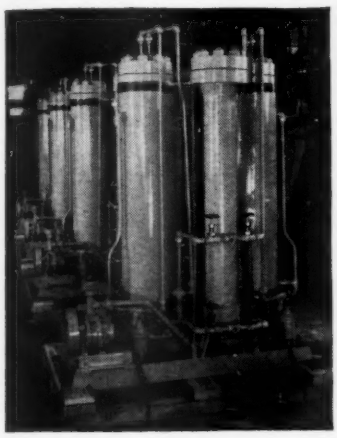

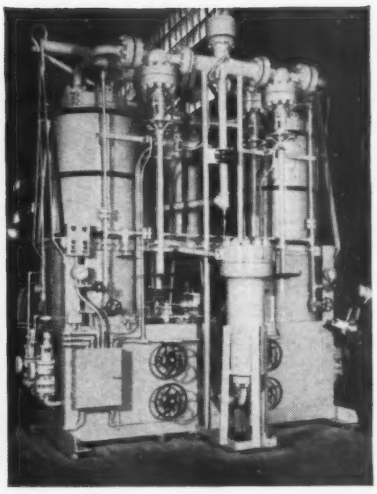

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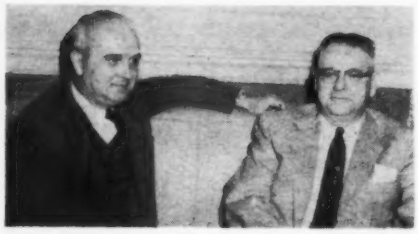


Left to right, R. C. Frederick, Gulf Oil Corporation, talks it over with Dr. E. D. Crittenden, Nitrogen division, Allied Chemical and Dye Corporation.

Frank H. Love, editor-in-chief of *The Petroleum Engineer*, talks shop with W. R. Brown, The Texas Company, and R. D. Ricketts, Fish Engineering Company.

Ray Riddle, Riddle and Hubble Company (left), looks for an answer as he talks with Gordon Cain (center), and "Doc" M. W. Conn, Perco division of Phillips Petroleum Company.

rated trays shows some reason to expect that this design may supply the conventional bubble-tray for careful fractionation. The same is potentially true in absorber service without reference to design of trays. Within the range of 20 to 40 trays in an absorber, actual tests on plant equipment have shown that the number of theoretical plates does not increase with increase in the number of actual plates installed; the work was done on an absorber by Stanolind Oil and Gas Company engineers. From this work, these men now question the advisability of employing an average overall plate efficiency value. The tests indicate a trend toward lower plate efficiency for individual components, as the volatility increases from the butanes through methane.

Perforated trays have been found "entirely satisfactory" for service in absorbers so far as capacity and efficiency considerations go, R. E. Kelley stated. In a test absorber, a perforated tray had greater capacity than did the bubble tray used originally. Estimates were worked out that indicate a single-pass perforated tray with blanking strips removed has essentially the same capacity as a four-pass bubble tray. The perforated tray is claimed to have additional advantages in initial cost and in lower pressure drop.

In carrying out an economic study to determine if a given amount of gas will justify the installation of a "vest pocket" gasoline recovery plant, the same factors must be evaluated as those studied in considering a large unit, says R. B. McLaughlin of Northern Natural Gas Company. The financial returns from the products will determine the possible revenue. The amount of gas will determine the size of equipment needed and also the cost of this equipment. The composition of raw gas along with quantity of the gas, will show the total production possible from the unit.

Although the portable gasoline plant idea has existed for some time, it required the present situation, where gas wastage is prevented by law, to bring out the careful consideration of the use of this type unit, he indicated. The total quantity of product that will be recovered by these small plants, when employed to prevent waste of natural resources, will add up to a respectable figure.

NGAA members registering early in the Dallas sessions.

B. L. Morgan (left), and K. L. Perrier, both of France Packing Company, compare notes on the meet.

A "Cozy Corner" with K. H. Clough (left), M. A. Smith, and Jim Cooper, all of W. H. Curtin Company, confabbing.

Severe corrosion in a glycol dehydrating unit in a gas line was improved by placing more cooling equipment upstream of the dehydrator to lower the gas temperature going into the unit; by adding a corrosion inhibitor (polyethanol rosin amine type) diluted with kerosine, at the rate of 0.1 gal per day for 6,000,000 cu ft of gas, and by reducing the amount of oxygen in the gas by admitting higher pressure gas to the compressor intake whenever the inlet pressure dropped to one psi. Results of this program, say Will Swerdloff and Maryann Duggan of Magnolia Petroleum Company indicate that while test coupons give indications of corrosion conditions, inspections are required to show how equipment is being affected by the program; also, that careful and continuous attention must be given to details of the routine to obtain maximum benefits from the treatments.

Warren Petroleum Vice President H. W. Harts, at left, swaps stories with Stanolind Oil and Gas Company's D. B. Edwards, center, and C. E. Wharton, also of Warren Petroleum.

Also at the meeting, a great number of industry problems were discussed: LPG problems and their solution; federal and state control of gas production, transportation and sale; equilibrium ratios and other technical matters important to the industry's operations; and these and other subjects filled the three days of sessions. * * *

REFINERY PLANTS SCHEDULED FOR COMPLETION

Cat reformer for Louisiana plant. The Southwest Gas Producing Company — Feasel Interests natural gasoline plant at Duback, Louisiana, will install a catalytic reformer unit, to upgrade all production to the 89-95 research octane number motor fuel range. Fish Engineering started construction in May, expects to complete and put unit on stream in September of this year.

★ ★ ★

Cat cracking unit for Italy. Socony-Mobil Italiana will build a new catalytic cracker, presumably a moving-bed. Thermofor unit, at its Naples, Italy, refinery. Amount to be spent is not announced, but Socony is reported to have bought about $11 million in "two types of U. S. Government guarantees" to cover the expenditure.

★ ★ ★

New West Coast chemical plant. Standard Oil Company of California has begun work on a new $16,000,000 chemical fertilizer plant. The new plant will manufacture ammonia and nitric acid and is being built at the company's Richmond, California, refinery. By-product hydrogen from oil refining operations will be used in making the ammonia.

★ ★ ★

Braun to build refinery. C. F. Braun & Company will be the contractor for the construction of a new $100,000,000 refinery to be built 15 miles south of Wilmington, Delaware, for the Tide Water Associated Oil Company. The plant will have a capacity of 130,000 bbl of crude oil daily and will include the largest catalytic cracker yet constructed, with a total charge capacity of 102,000 bbl daily. The new facility will also include the largest fluid coker ever constructed, with a capacity of 42,000 bbl per day.

★ ★ ★

Ammonia plant for Puerto Rico. A new, 12¼ million anhydrous ammonia plant is scheduled for building in Puerto Rico soon, says L. R. Gonzalez, Gonzalez Chemical Industries president, San Juan. Unit is to be financed via Glore, Forgan & Company, four insurance companies participating. Local banking facilities will make up the balance of the money needed, the route being through issuance of bonds. Unit, located on Guanica Bay, south coast of the island in deep water, will make 42,000 tons per year. Lummus company will design and build; Cox & Weinrich, Washington, D. C., are engineering consultants for the chemical company.

★ ★ ★

Canadian cracking catalyst unit. Canadian subsidiary of Davison Chemical Company, will build a $6,000,000 fluid cracking catalyst plant near Montreal, Quebec, Canada, that will supply all of this catalyst needed by Canadian refineries. Site has been acquired and design and engineering plans have been made up by Badger division of Stone & Webster Engineering Corporation. Reports say construction work is well under way.

★ ★ ★

Caltex-Sarpom Expansion in Italy. Construction of a new catalytic cracker, a polymerization plant and a vacuum unit are the main items in the current expansion of this refinery at San Martino de Trecate, Italy. A 97-mile, 8-inch pipe line connects docks on the Gulf of Genoa to the refinery, handling 12,500 bbl per day of tanker-borne crude for the plant's operations.

★ ★ ★

Cat Reformer for Germany. A 3500 bbl per day Houdriformer unit has been contracted for by G. E. Raffineris Emsland, at Lingen, Germany, with Houdry Process Company and the Lummus Company, engineers and builders. Unit will be completed by late 1955, and will augment the output of the 17,500 bbl per day Houdriflow unit in the plant.

★ ★ ★

Carter's Hydrofiner-Cat-Reformer. A 6900-bbl hydrofiner unit and a 2500-bbl catalytic reformer unit will be built immediately at the Billings, Montana, refinery of Carter Oil Company, Esso Standard subsidiary. Fluor Corporation has the contract, expects to complete by January 1956. Design includes four 70-ft towers, furnaces, compressors, reactor vessels and auxiliary items.

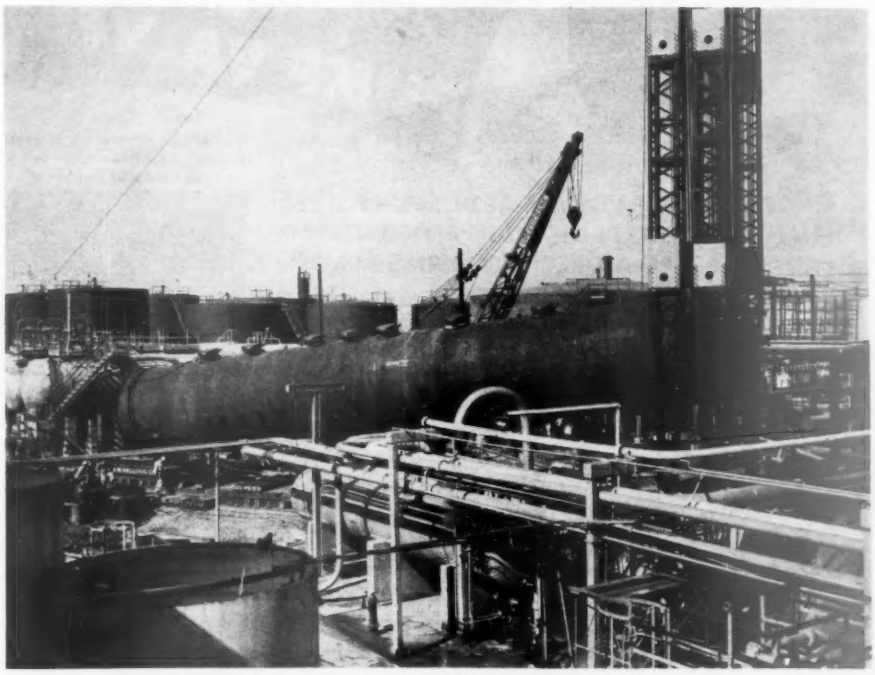
Foster Grant expands styrene capacity. Boosting its styrene monomer capacity at Baton Rouge, Louisiana, from 24,000,000 lb to 50,000,000 annually, using a German process for the synthesis, this company is already shipping styrene to Copolmyer Rubber & Chemicals plant nearby. The latter is one of the first government-owned rubber plants turned over to private purchasers. Part of the new capacity will supply the monomer to the polymerization unit at Leominster, Massachusetts, which was also expanded.

★ ★ ★

More expansion, Montreal East. A $14,000,000 bill for expansion of its Montreal East, Canada, refinery from 44,000 bbl to 55,000 bbl per day capacity will be incurred by Shell Oil of Canada between now and mid-1956. A new vacuum flashing unit, and a boost to cat cracking capacity from 16,500 to 19,500 bbl per day, will cost $4,000,000. These additions are already under way and will be completed by the end of 1955. A. G. McGee Company is building the vacuum unit, company staff the cat cracker expansion. A 15,000 bbl per day crude unit is being rebuilt to handle 26,000 bbl daily, also by McKee. A cat reformer and hydro-desulfurizer will start construction this summer, by Procon Ltd.

★ ★ ★

Spencer plans expansion. Spencer Chemical Company plans to spend $1.5 million at Vicksburg, Mississippi, to raise its capacity for making ammoniating solutions and nitric acid; quantities are not yet mentioned.



A New 306-Ton Deresining Tower, the heaviest of its kind ever erected in one piece in the world, is raised into position on its new home site at Humble Oil and Refining Company's Baytown refinery. The new tower is 94 ft long, 13½ ft in diameter and has steel walls more than 3 in. thick. The Texas-size tower was designed to improve the manufacture of lube oils.

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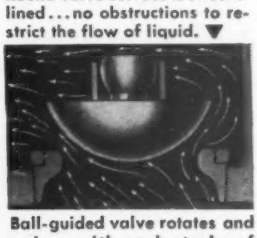
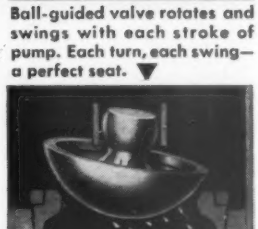
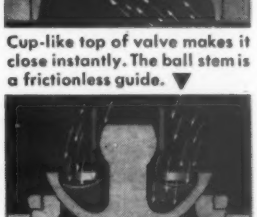


Ball-guided valve rotates and swings with each stroke of pump. Each turn, each swing—a perfect seat. ▼



Cup-like top of valve makes it close instantly. The ball stem is a frictionless guide. ▼



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Shale unit plans in progress. Union Oil Company of California has picked Stearns-Roger Manufacturing Company as engineer on its planned shale demonstration plant in Colorado. The engineers and the company's research department are working together to determine the plant site, construction schedules and other details, that include a 1000-ton-per-day shale retort. Company has 50,000 acres of oil shale holdings; it will work in Colorado and in its California laboratories to discover the costs of a large shale unit and to determine the profitability of shale oil development, spending a total of $5,000,000 on the program.

★ ★ ★

New Catalyst Unit for Canada. A $6,000,000 plant near Montreal, to be built by Davison Chemical Company, Ltd., Canadian subsidiary of the Davison company of the U.S., will be under construction soon. Badger division of Stone & Webster Engineering Corporation is to design and engineer the plant, which when operating will meet at Canada's needs for fluid cracking catalyst.

★ ★ ★

Gasoline Testing Laboratory. A new laboratory for testing gasolines is to be built in Houston, Texas, by Ethyl Corporation for service to the refiners of the West Coast region, to be completed later this year. This will be the sixth service testing laboratory operated by Ethyl. New facilities will include an X-ray photometer, with which tetraethyllead content of a motor fuel can be determined in about six minutes, a much shorter time than is required by conventional analytical methods.

★ ★ ★

Magnolia-Phillips Gasoline Plant. In Garvin County, Oklahoma, a gasoline extraction plant of undisclosed capacity will be built soon, to recover natural gasoline and LPG liquids from gas from N.W. Purdy, West Lindsay and Bradley area fields. A new, 140-mile, 24-in. line will be laid by Transok Pipe Line Company to carry the dry gas to Tulsa, where it will supply fuel for Public Service Company's power generating station.

★ ★ ★

Big crude unit for Whiting. A 55,000 bbl per day crude distillation unit will be built for Standard Oil of Indiana at its Whiting, Indiana, refinery by C. F. Braun Company. This unit will boost the plant's crude capacity to 220,000 bbl per day and will start operating early in 1956. Also planned are a 6000 bbl per day Ultraformer unit, and other facilities for its Mandan, North Dakota, plant built last year.

★ ★ ★

First Yorktown plant contract let. Contracts for building a 35,000 bbl per day crude unit and a 30,000 bbl per day fluid catalytic unit and polymerization unit have been let by American Oil Company, to M. W. Kellogg Company, unit to be the first in the Yorktown, Virginia, refinery. Other contracts for preparing site and port facilities have been let.

PIPE LINE DEVELOPMENTS

★ ★ ★

Roundup of Current Planned and Proposed Construction

NAME OF COMPANY	MILES	PIPE SIZE	LOCATION
CRUDE LINES			
Ar-Mex Pipeline Co.	790	12-14	Guernsey, Wyoming to Coolidge, Arizona
Big Horn Pipe Line Company	150	8	Ash Creek field to Midwest station of Service Pipe Line, Wyoming
Butte Pipe Line Company	455	16	Williston Basin area of Eastern Montana to Gurley and Ft. Laramie, Wyoming
Kaybee Pipe Line Company	46	10	Griffith, Indiana, to New Buffalo, Michigan
Michi, Inc.	222	10	Highland, Indiana, to Elsie and Alma, Michigan
NNCW Pipe Line Co.	127	8-10	Weston County to Casper, Wyoming
Orchard Pipe Line	45	8	Orchard to Merino, Colorado
Peace River Oil Pipe Line Co., Ltd.	200	12-16	Peace River area to Edson station on TransMountain near Edmonton, Alta
Powder River Pipe Line Company	436	10-16	Williston Basin to Laurel and Billings, Montana
Proven Oil & Refining Company	32	8	Connection with West Coast Pipe Line to Florence, Ariz.
Roosevelt Oil & Refining Corp.	22	4.6	St. Helen to Norwick, Michigan
Skelly Oil Company	14	6	Lines in Reno and Kingman counties, Kansas
Sinclair Pipe Line Company	31	12-16	Monee to Lemont, Illinois
West Coast Pipe Line Company	960	20-22	Wink, Texas, to Norwalk, California
U. S. Department of Defense	97	—	Crude line from Elk Hills Naval Reserve to Los Angeles, California
PRODUCTS LINES			
American Pipe Line Company	1910	8 to 26	Beaumont, Texas, to Newark, New Jersey, with laterals
Ar-Mex Pipe Line Company	130	8	Tucson to Coolidge to Phoenix, Arizona
H. W. Bass & Sons, Incorporated	152	4-6	Duval and Live Oak counties, Texas, to Corpus Christi, Texas
Bell Oil and Gas Company	140	6-8	Ardmore to Cushing, Oklahoma
Bowen Oil and Management Company (LPG Line)	460	10	Midland to Texas City, Texas
Buckeye Pipe Line Company	200	8	Conversion of existing crude line from connection with Wolverine Pipe Line near Michigan-Ohio border to Cleveland, Ohio
California-Oregon Pipe Line System	103	6	Crescent City, California, to Medford, Oregon
Deep Rock Gas Company (LPG Line)	120	6	Tioga, North Dakota to U. S. Canadian Border
El Paso Natural Gas Co. (LPG Line)	119	3-6	Bloomington to Gallup, New Mexico
Goliad Corporation (LPG Line)	117	4-6	Kittie Plant to Corpus Christi, Texas
Inland Corporation	37.5	10	Toledo to Fostoria, Ohio
International Pipe Line Inc.	132	8	Wrenshall to Minneapolis, Minnesota
Keystone Pipe Line Company	48	8	Boot Station to Fullerton, Pennsylvania
Malco Pipeline, Inc.	91	6	Prewitt to Albuquerque, New Mexico
Mayflower Pipe Line Company	400	10	New Jersey refineries to New England points
Moore-Stoner Company	200	6	Glendive, Montana, to Minot, North Dakota
Phillips Petroleum Company	50	—	Ethylene line from Sweeny to Pasadena, Texas
Shamrock Pipe Line Corp.	100	6	Amarillo to Abernathy, Texas
Sioux Oil Company	50	6	Newcastle, Wyoming, to Rapid City, South Dakota
Socony-Vacuum Oil Co. Eastern Pipe Lines	5	12	Linden, New Jersey to Port Socony on Staten Island, N. Y.
Southern Pacific Pipe Lines Company	800	6 to 16	New products lines system in California, Arizona, New Mexico and Texas to be built and operated by Southern Pacific Railroad Co.
Standard Oil of Indiana	47	8	Manhattan to Lemont, Illinois, and Manhattan to Chicago River Terminal
Sunflower Pipe Line Company (LPG Line)	265	3-6	Kearny, Grant and Haskell counties to Wichita, Kansas
Texaco-Cities Service Pipe Line Company	45	8	West Tulsa to Cushing, Oklahoma
Winnipeg & Central Gas Co. (LPG Line)	330	6	Tioga, N. D., to Winnipeg
GAS LINES			
Alberta Gas Trunkline	315	18-36	Gas Gathering System in Alberta fields
American-Louisiana Pipe Line Company	1120	22 & 30	Lowry, Louisiana, to Detroit, Michigan
Arkansas-Louisiana Gas Company	136	8 to 24	Loops on System
Central Hudson Gas and Electric Co.	48	12	TGT line to Kingston, N. Y.
City of Fayette, Alabama	20	5	Fayette, Alabama, to Southern Natural's system
Coast Counties Gas Electric Company	40	3-4-8	Coast and Valley Region, California
Coastal Transmission Corporation (c/o Delhi Oil, Dallas)	400	30	McAllen to Beaumont, Texas
Colorado Interstate Gas Company	365	22	Green River, Wyoming to Denver, Colorado
Colorado Interstate Gas Company	110	6-8	Julesburg area to Denver, Colorado
Colorado-Western Pipe Line Co.	328	16-18	Ignacio field to Pueblo and Denver
Colorado-Western Pipe Line Co.	454	—	Cortez to Denver System
Colorado-Western Pipe Line Co.	250	—	Lateral lines
Cumberland and Allegheny Gas Co.	31	12	Garrett County, Maryland, to Keyser, West Virginia
El Paso Natural Gas Co.	370	—	Mountain Home, Idaho, to Reno, Nevada
El Paso Natural Gas Co.	74	—	Additions to Permian Basin-San Juan Basin system
Fort Worth Basin Gas Company	—	—	Brown and Comanche counties, Texas
Kansas-Nebraska Natural Gas Company	206	6-12	Additions to Nebraska system
Manufacturers Gas, Light & Heat	40	—	Allegheny, Washington, and Beaver counties, Pa.
Manufacturers Gas, Light & Heat	213	3 to 26	Various points on system in Pa., W. Va. and Ohio
Manufacturers Gas, Light & Heat	72	16-20	Doddridge, Wetzel and Marshall counties, West Va.
Michigan Consolidated Gas Company	25		Sparta to Muskegon, Michigan
Michigan-Wisconsin Pipe Line Company	252	4-24	Loops and stations in Illinois
Mississippi River Fuel Corporation	190	10-18	Laterals in Woodlawn and Waskom gas fields, Texas
Morganfield Natural Gas	31	4-6	Through Sturgis, Providence, Clay, Diamond, Wheatcroft and Sullivan, Kentucky
Natural Gas Pipe Line Co. of America	350	20-26	Amarillo to Wise County, Texas
Natural Gas Producer, Inc.	100	12	Yenter pool to Denver, Colorado
Natural Gas Producer, Inc.	61	4-10	Northeast Colorado lines
Natural Gas Storage Company	35	36	Storage field areas near Chicago to main lines
New River Gas	50	—	Sumners to Monroe counties, West Virginia
North Dakota Natural Gas Company	475	6-12	Statewide system in North Dakota
Northern Indiana Fuel & Light	35	8	Edgerton to Alburn, Indiana
Northern Natural Gas Company	330	2-12	System in South Dakota
Northern Natural Gas Company	310	24	Lines in North Dakota
Northern Natural Gas Co.	403	24-30	Canadian border to Minneapolis-St. Paul
Northwest Utilities Ltd.	42	—	Bonnie Glen to Edmonton, Alberta, Canada
Pacific Northwest Pipeline Corp.	1486		Ignacio, Colorado to Bellingham, Washington
Pacific Northwest Pipeline Corp.	380		Laterals and spurs off main line to Pocatello, Idaho, to Yakima, Washington
Pine Tree Natural Gas Co.	204	—	Boston to Bangor, Maine
Rockland Light & Power Company	22	8	Orangetown to Tompkins Cover, New York
Shenandoah Gas Company	39	3-4-8	Middleton, Virginia, to Martinsburg, West Va.
Tennessee Gas Transmission Co.	221	26 & 30	Loops in Ohio and Kentucky
Tennessee Gas Transmission Co.	376	6-24	Gathering lines in Louisiana and Texas
Texas Eastern Transmission Corp.	328	24	Beaumont to Kosciusko, Mississippi
Transcontinental Gas Pipe Line Corporation	125	—	Ulster County, New York (Pheonica) to New York City
Trans-Canada Pipe Lines, Ltd.	2247	14-34	Alberta area to Toronto, Montreal
Union Gas Company of Canada	180	—	Dawn Storage field to Hamilton
United Natural Gas Company	50	12	Elk County to Jefferson County, Pennsylvania
Utah Natural Gas Company	40	16	Orem to Salt Lake City, Utah
Virginia Natural Gas Company	153	—	Buckingham to Richmond and Portsmouth, Va.
Warren Petroleum	54	4-30	Lea County, New Mexico
Westcoast Transmission Co., Ltd.	650	30	Peace River area, Alberta, to U. S.-Canadian border
Wilcox Trend, Gathering System, Inc.	16	6	Loop near Provident City, Texas. Also plans additions to gathering systems.
Wyoming Gas Products Corp.	—	—	Gas gathering system in Weston County, Wyoming

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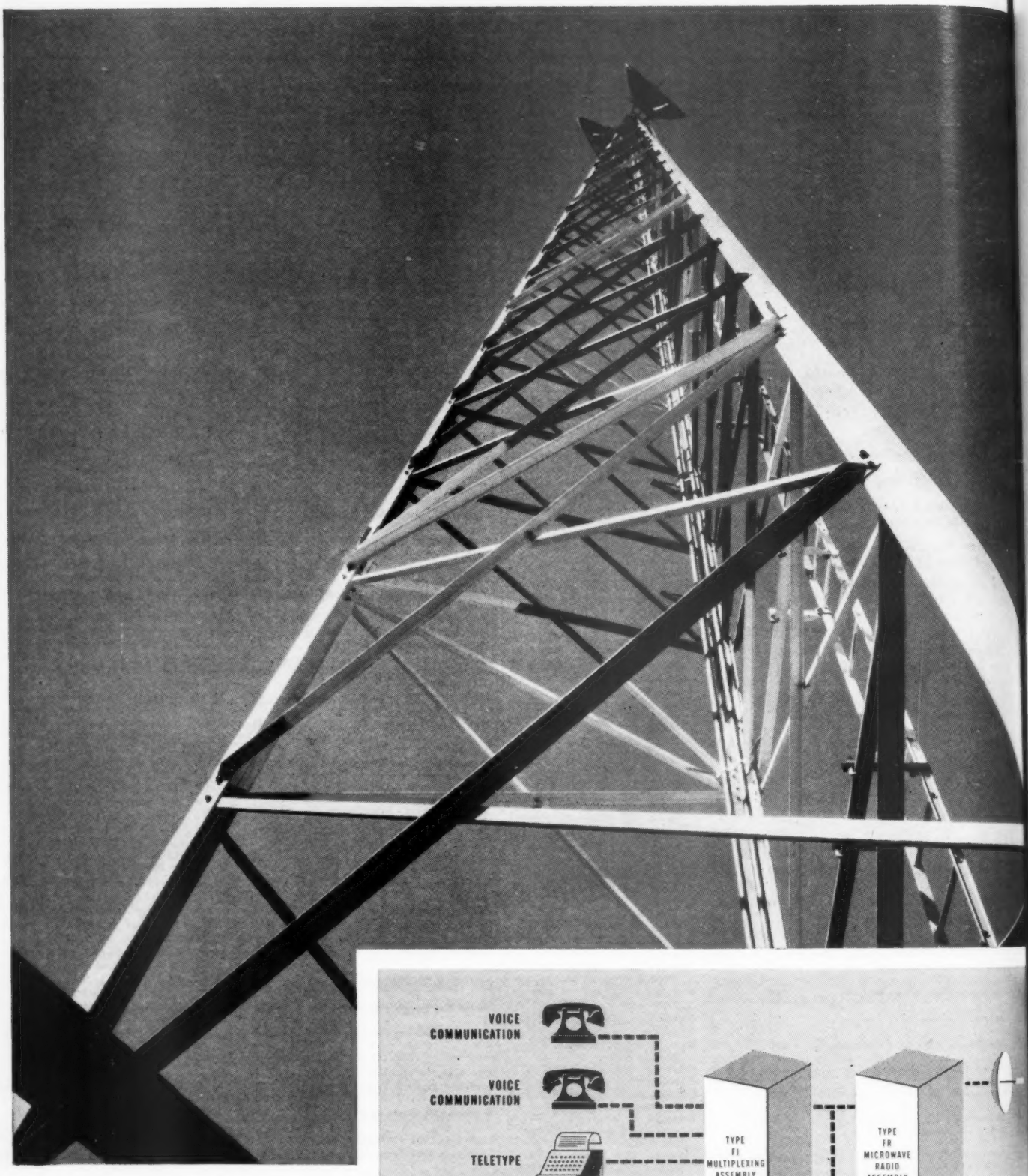

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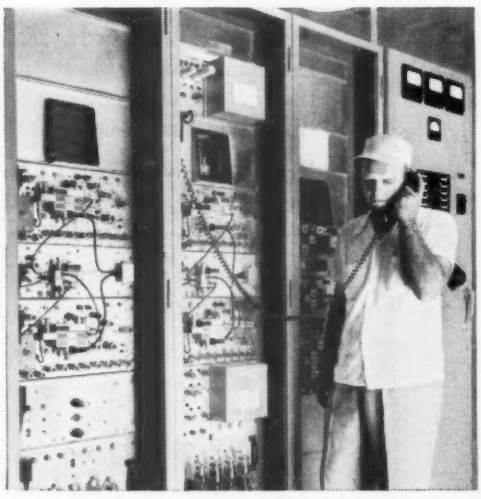
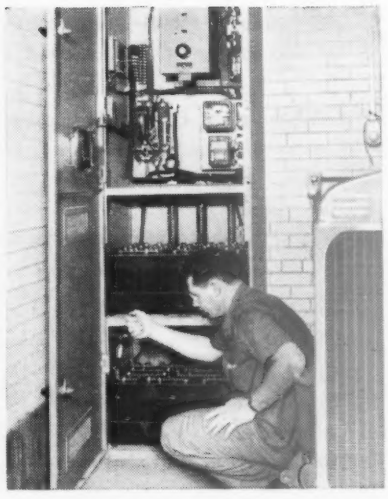


Service channel gives contact with maintenance crew, speeds servicing. Completely independent of the operating channels, it does not interfere with their functions.



Extra reliability is provided by automatic switchover to stand-by radio and stand-by power. Shown here is a 5-kw generator set with engine starting and battery cabinet.

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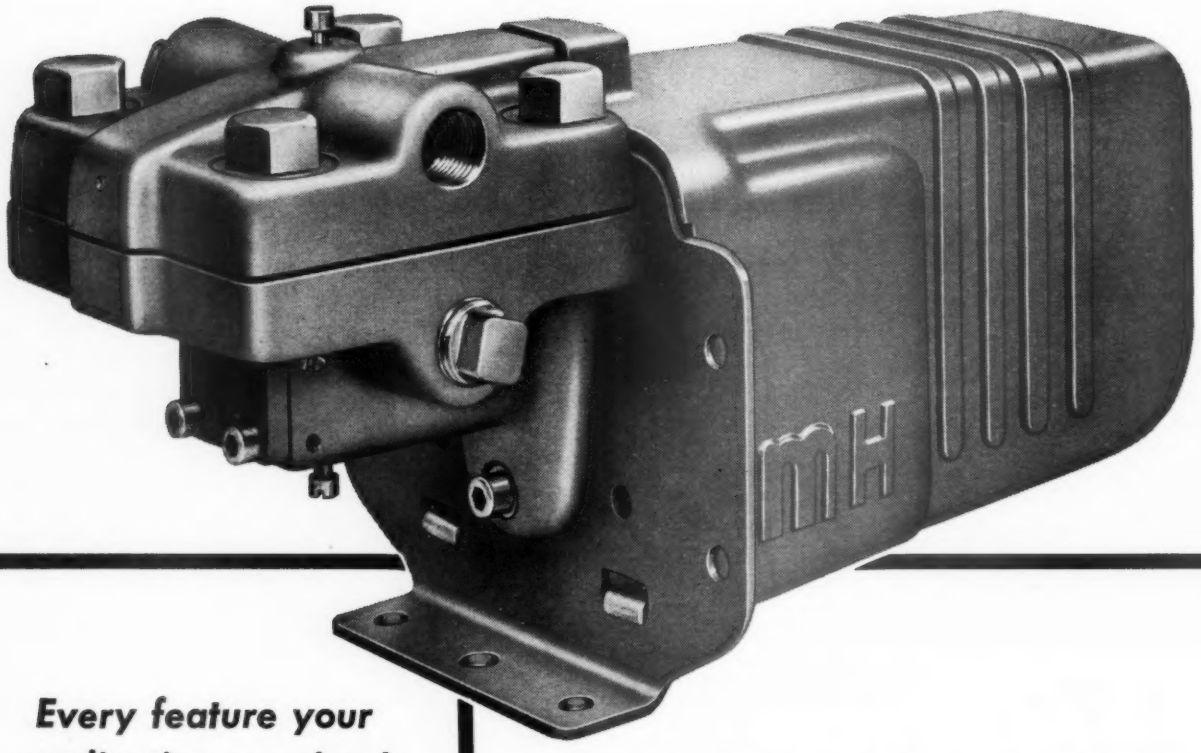
Pace-setting performance for liquid level and flow measurements— *the Honeywell Differential Converter*



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THE MERCURYLESS remote transmitter that has set new standards of performance in flow applications—the Honeywell Differential Converter—is now available in a new model for liquid level measurements in closed vessels. Suitable for use with either pressure or vacuum vessels, this model offers all the features of fast response, precision, convenience and ruggedness that have earned the Differential Converter wide acceptance throughout industry.

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● **REFERENCE DATA: Write for Bulletin 2291, "Differential Converter Liquid Level Transmitter," and for Bulletin 1160, "Measuring and Controlling Liquid Level."**

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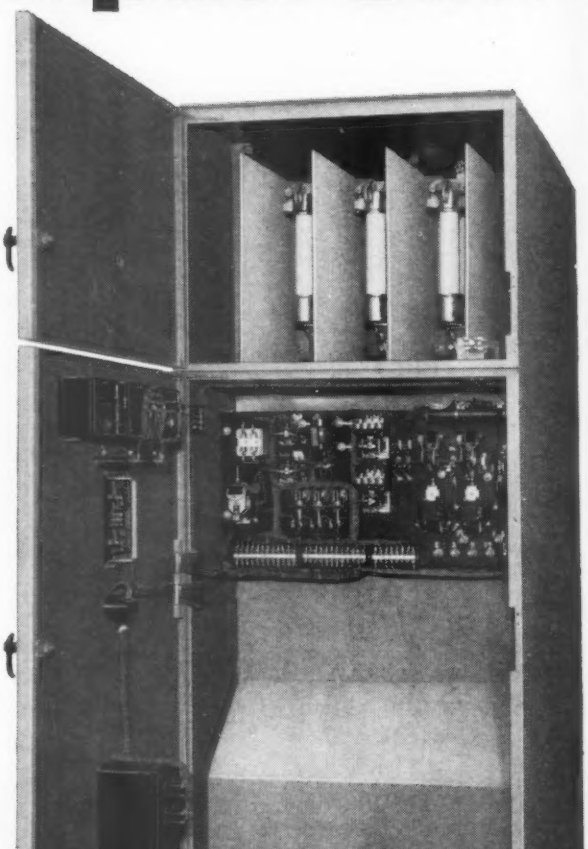

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To obtain more information on products advertised see Page E-43

Attention, producers: profit with Adomite*

What it is. Adomite is a newly developed and *thoroughly tested fluid-loss control additive* for converting lease crudes to superior fracturing fluids.

What it does. Adomite effectively seals the fracture face and practically prevents loss of fluid into the producing formation. This results in longer fractures and deeper penetration of sand for a given job. Adomite also cleans up rapidly and does not contaminate the produced oil or the formation.

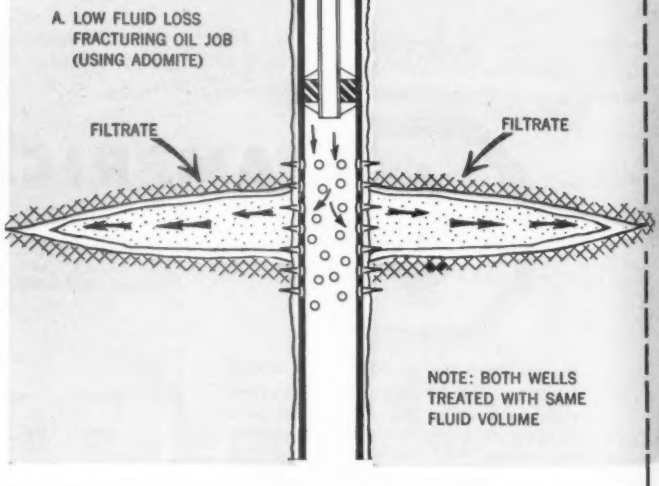
How you profit. You get *greater sustained production* with a given fluid volume *at much lower cost.* Adomite may also enable you to make significant fractures in formations which have proved difficult to fracture with conventional techniques.

Form and availability. Adomite is a dry material in flake form now available through fracture service companies.

Utility. Adomite is easy and convenient to use. It is mixed directly into the crude or gelled crudes on the lease using only the standard mixing equipment necessary for fracturing. If the operator prefers a viscous material, Adomite may be used to reduce the fluid loss of gelled crudes offered by many service companies.

Adomite is equally effective in oils which have or have not been treated with emulsion breakers. It will tolerate small percentages of water sometimes present in crude on the lease and has little or no effect on viscosity of the oil. When Adomite is used, neither the formation nor the well's early production is contaminated with heavy residuals.

How it works. Adomite greatly retards fluid loss into the formation. Thus *more* fluid is retained to extend the fractures, allowing the sand to penetrate more deeply to sustain increased production.



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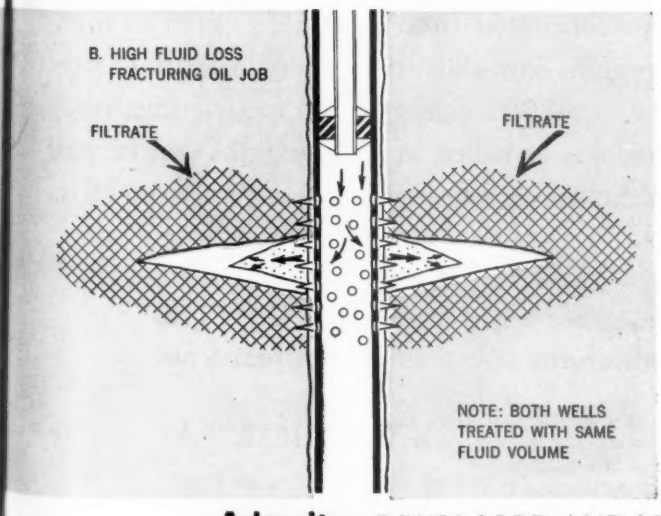
Adomite gives greater fracture area at lower cost than when conventional high fluid-loss type fluids are used. Thus, the BOPD is greater and the cost of the fracture job is much less.

To date, Adomite has been used successfully in over 500 fracture jobs in different fields. Following are examples of actual cases showing typical results obtained when fracturing is done with lease crude to which a small fraction of a pound of Adomite per gallon has been added.

1. Sustained Fracture Production—*Oklahoma.* First well fractured with Adomite in June, 1954. Production increased from 8 to 50 BOPD. Production 10 months later still 50 BOPD. *Wyoming.* Well fractured with 5,000 gallons Adomite-treated lease crude and 5,000 pounds sand. Production increased from 25 to 40 BOPD immediately following fracture. Six months later production was 65 BOPD.



2. Increased Production—*West Texas.* Well fractured with 10,000 gallons Adomite-treated lease crude and 20,000 pounds sand. Production increased from 75 to 576 BOPD.

3. Refracturing—*Kansas.* Well fractured with 10,000 gallons Adomite-treated lease crude and 12,000 pounds sand. Flowed 216 BOPD. This was third time well had been fractured, the two previous times having been with conventional fluid. Well had been shut in before fracturing.

4. Difficult Treating Area—*South Louisiana.* Well fractured with 10,000 gallons Adomite-treated lease crude and 10,000 pounds sand. Production increased from 0 to 160 BOPD. Previous fracturing in area sanded out at less than 2,000 pounds sand with conventional fluid.

5. Reduced Treatments—*West Texas.* In a field, 10,000 gallons of Adomite-treated crude oil injected at 8 bbl./min. gave as good, or better, results than were obtained in offset wells treated with 20,000 gallons conventional type fluid, injected at 40 bbl./min.

6. High Bottom Hole Temperature—*South Texas.* Adomite-treated lease crude has been used to put away 6,000 pounds sand in a formation having a temperature of 245°F. Ordinary fluids break down at this temperature.

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Ask your service company to use Adomite on your next fracture job

Adomite—DEVELOPED AND MANUFACTURED BY CONTINENTAL OIL COMPANY

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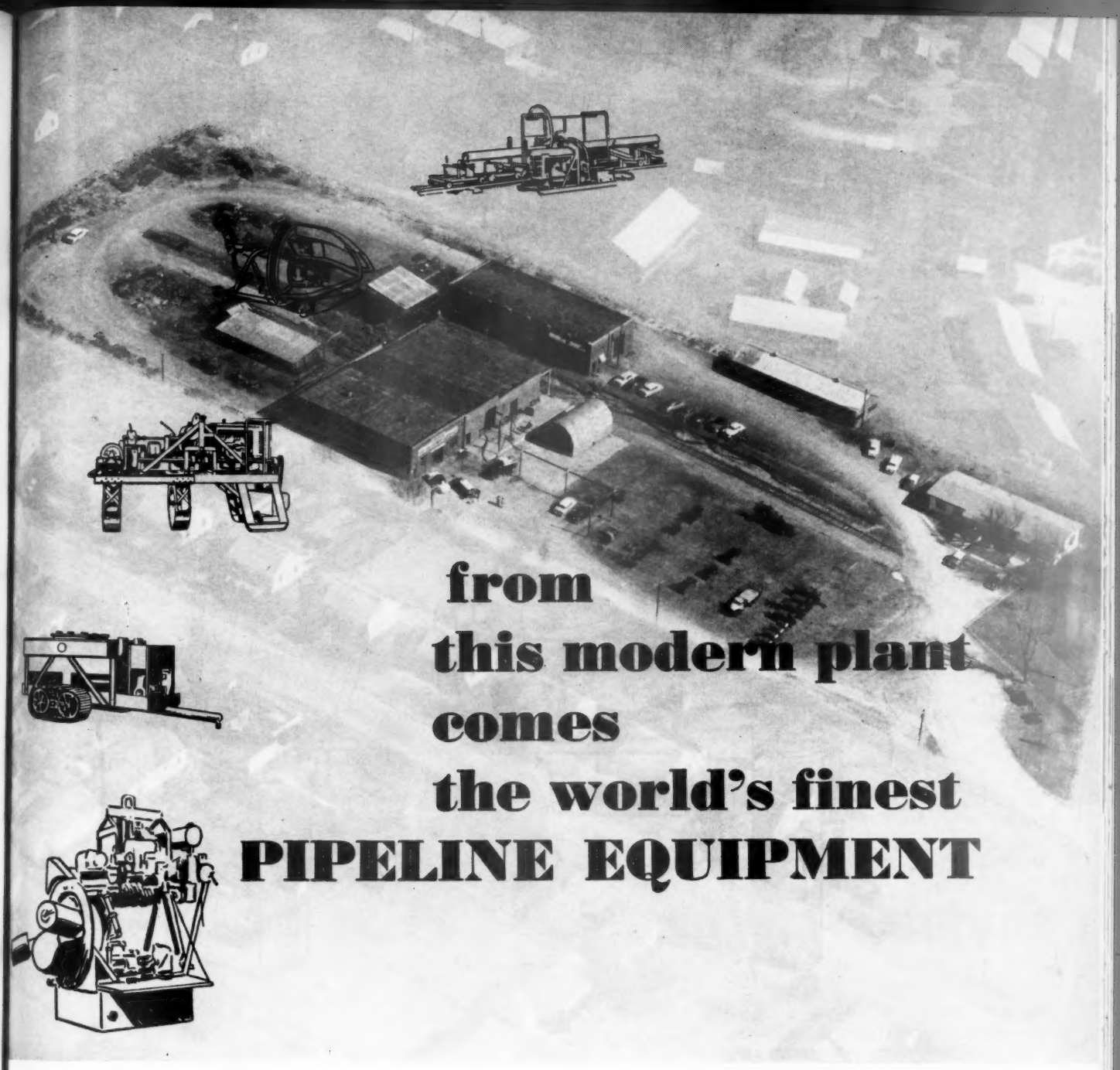

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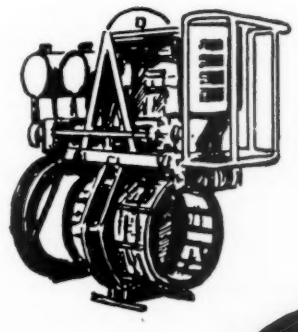

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Alternate routings are an integral part of planning by communications engineers to protect your service and prevent interruptions.

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We supply the pipe line industry with reliable private line telephone and teletypewriter service and provide channels for telemetering and supervisory control.

• • •

Bell System communications engineers will be glad to survey your communications needs without charge. Call your Bell Telephone representative today.

BELL TELEPHONE SYSTEM

TELEPHONE TELETYPEWRITER MOBILE RADIO TELEMETERING AND REMOTE CONTROL CHANNELS

View of dispatcher's office at Gulf Interstate Gas Company's headquarters in Houston. In addition to transmittal of standard messages, the teletypewriter machine in rear of room also serves to report automatically telemetered operational data from key points on the company's pipe line system.

Gulf Interstate Uses Telemetering System to Obtain Operational Data

Digital Telemetering Via Teletype

Sy Orlofsky*

EXCLUSIVE

This is the second of two articles describing the communications facilities employed by Gulf Interstate Gas Company, newest of the nation's major natural gas transmissions systems. The first article, which appeared in the May issue of The Petroleum Engineer, ***covered the full-period telephone, VHF radio and teletype channels, which provide the principal components of Gulf Interstate's communications network. The accompanying story describes in detail the operation of the company's amazing new telemetering system.***

THE PROBLEM OF ACCURATELY AND rapidly transmitting necessary operating information from remote locations to a central control point is one that is faced by nearly every pipe line company. Information from compressor stations and measuring points hundreds and even thousands of miles distant must be transmitted to the control center of the system in order to insure proper and efficient operation.

Gulf Interstate Gas Company faced this problem when planning its new transmission system. It was necessary that regular operating reports be obtained from five compressor stations and six measuring stations, which were distributed over 1160 miles of pipe line extending from southern Louisiana to the Kentucky-West Virginia border. The information from these points was needed in the central dispatching office located at the company's headquarters in Houston.

Since the 8000-hp compressor sta-

*General Superintendent, Transmission Department, Gulf Interstate Gas Company, Houston, Texas.

View of field clerk's office at one of Gulf Interstate's main line compressor stations, reflecting various communications media available to operating personnel. At right are VHF radio transmitter and telephone instrument which carries full-period leased circuit as well as local and intercommunications lines. (The radio and full-period channel may be integrated when necesary). At left is teletypewriter machine and tape cutter, and in center of picture are cabinets containing telemetering equipment used to relay automatically operating data through teletype circuit.

Interior view of one of the 11 mobile maintenance centers operated by the Bell System adjacent to Gulf Interstate's 1160-mile right-of-way. These centers provide for rapid repair of VHF radio, telephone and teletype equipment leased from the telephone company.

FIG. 1.

Pressure	Transducer Output	Fixed Frequency	Difference
(PSI)	(CPS)	(CPS)	(CPS)
950	9050	10000	950
550	9450	10000	550

FIG. 2.

01 250 02 250 03 245 04 000 06 782

010 1 707 2 707 3 935

TYPICAL PRESSURE-RPM TRANSMISSION

tions were designed to be operated by only one man on a shift and because the measuring points were unmanned in many cases, an automatic means of data transmission was deemed essential. Telemetering appeared to be the most efficient method available.

In the interest of economy, it was desirable that the medium selected to carry this operating information be one that could be used for other types of communications. Leased line telephone and leased teletype circuits were already planned as integral features in the company's communication system. Either of these appeared adaptable to automatic information transmission. The normal anticipated load on the telephone circuits was so high, however, that there was considerable doubt as to its practicability as a telemetering media. Also, the use of the telephone circuits in emergency conditions was absolutely necessary, rendering them impractical as a telemetering channel. Attention was therefore turned to the teletypewriter circuit, which was to be installed as regular equipment. Load surveys indicated that sufficient free time would be available on this circuit for telemetering purposes.

Selection of the teletype circuit immediately suggested the use of a teletype receiver as a recording device. This machine would allow recording of information in digital form, rather than on a chart. This digital record is highly desirable for its speed and accuracy. A digital record printed on a teletype machine is less subject to error in interpretation than is a record made on a chart.

It therefore appeared that digital telemetering via teletype circuits, with a standard teletype machine as a recorder, offered the best possibilities for a system that would provide Gulf Interstate with automatic transmission of essential operating data. No additional system of communication was needed for this purpose, as the teletype circuit was to be installed in any event. Aside from the economic advantage, the digital recording of operating information would provide an accurate and easily read record.

With these advantages in mind, work was begun on the design of such a system by Gulf Interstate Gas Company, the Berkeley division of Beckman Instruments, and A. T. & T. engineers.

How Does It Work?

By starting with the final result of the telemetering system the mechanics and operation of this equipment can best be described. When the dispatcher in Houston wishes to interrogate one of 11 telemetering points on the pipe line system, he depresses a combination of two buttons keyed to that station and

the operation begins immediately. Within seconds the information is automatically transmitted and recorded on the dispatcher's teletype machine. A typical transmission is shown in Fig. 1.

The data in Fig. 1 is a copy of an actual transmission received from Gulf Interstate's Rayne, Louisiana, compressor station. The form of this telemetered information is identical for all compressor stations, an dis interpreted as follows:

010 : This is the station code number, and is peculiar to the Rayne station. All other transmission points have a code number and automatically transmit their identification at the beginning of each message. Thus, the information source is readily verified by merely glancing at the first numbers of the message.

1 : This identifies the function whose value is about to be received. Each function has a code number. The functions are always transmitted in the same sequence, so there is no chance of confusion. In this case, *"1"* represents the code number for the pressure on one of the suction lines to the compressor station.

707 : This number is the pressure on the line being checked, in pounds per square inch gage pressure. This is the actual pressure and no factors need be applied for true reading.

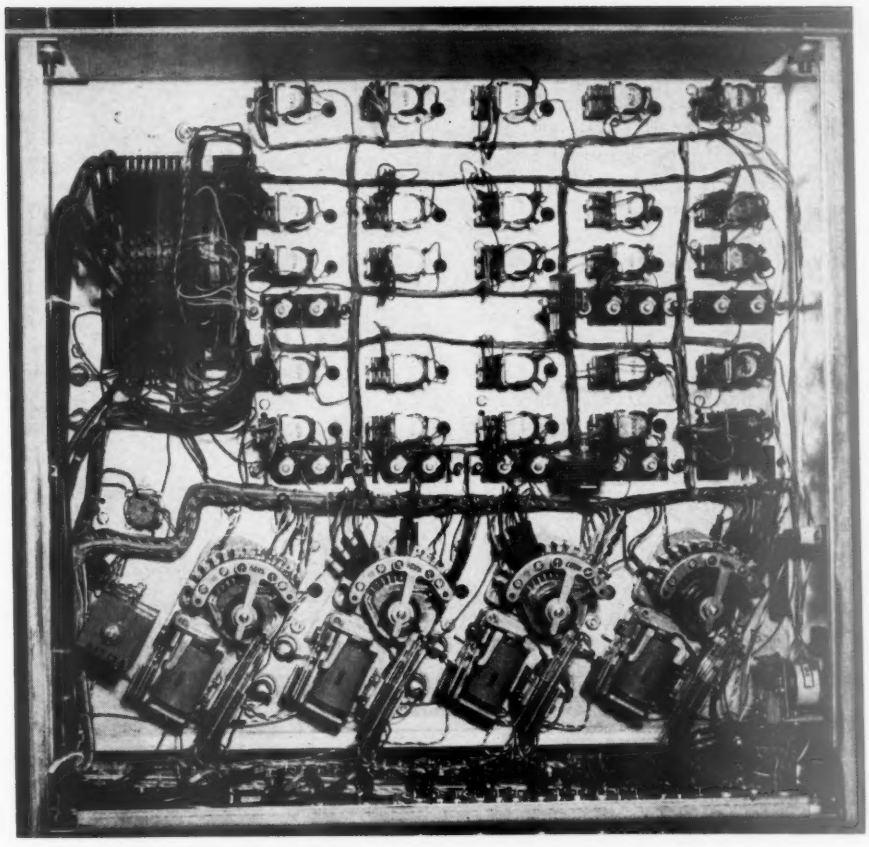
2 : This code number identifies the second function transmitted; in this case, the pressure on a second suction line entering the Rayne station.

707 : This again is the actual pressure on the line. The fact that this line is at the same pressure as the previous reading is not coincidental. At the time of the telemetered transmission the station was operating on a common suction.

3 : This is another function designation; in this case identifying the discharge pressure at the Rayne station.

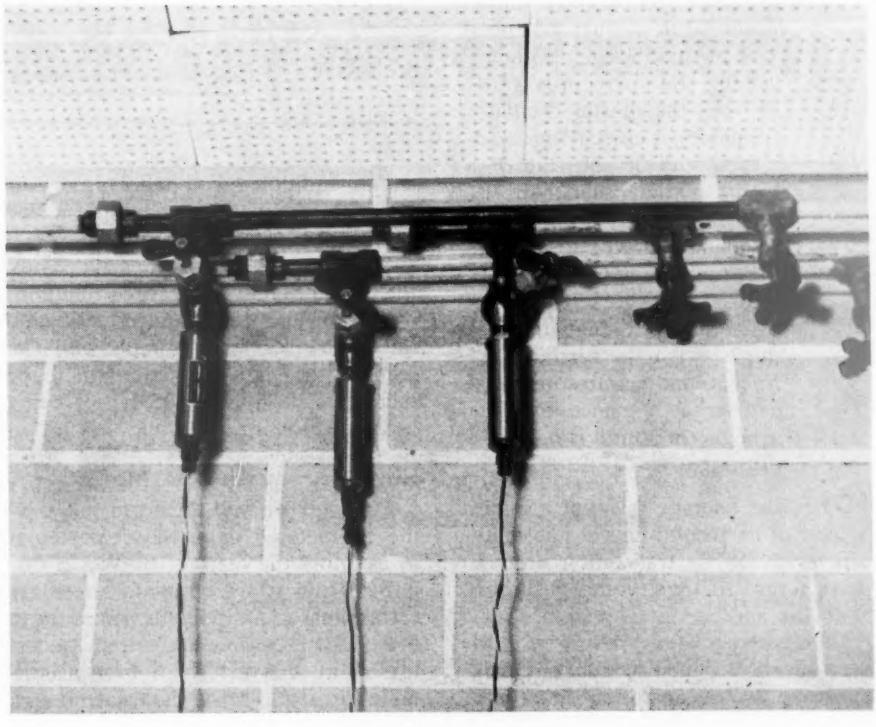
930 : This is the actual discharge pressure of the station, in pounds per square inch gage.

The above information is printed on one line of the paper roll in the teletype machine at Houston. The spacing between the various segments of the transmission is constant and automatic, and will be the same for all transmissions.



Close-up view of the stepping switches and relays used in the control unit of the telemetering equipment installed on Gulf Interstate's pipe line. It is this apparatus that makes possible the conversion of data to a form for transmission and the sequential transmission of the information in standard form.

These pressure transducers—manufactured under the trade name of Vibratron—produce a frequency output that varies with the pressure in the discharge and suction lines at Gulf Interstate's compressor stations. The transducers are located in the office building at the station.



XUM

Interpreting Second Line

When the end of this first line has been reached, the teletype machine automatically shifts to the left, and the line feed operates to move the paper up for transmission of the next line. The interpretation of the second line of Fig. 1 is as follows:

01 : This is again a code number, identifying the speed measurement of compressor engine No. 1.

250 : This is actually the engine speed, in rpm of No. 1 compressor engine.

02 : This is a code designation for the speed of engine No. 2 in rpm.

Following is the actual speed of engine No. 2.

The next numbers are the code designations and speeds for engines 3 and 4, respectively. The speed will register as 000 on any engine that is not running.

06 : This is a code designation for test frequency.

782 : This is a test frequency, transmitted to show the receiving station that transmitting and detection equipment is functioning properly. The *782* is simply a 100-kc frequency taken from the crystal controlled oscillator on the counting unit, and divided by seven binaries, to a resulting frequency of 781.25. This reading is detected and transmitted in the same manner as a pressure or rpm. So long as the receiving station records a 781 or 782, the master oscillator frequency is correct and readings should be accurate. If a reading other other than 781 or 782 is received, the master frequency is off and all readings transmitted may be in error. The check frequency is simply a safeguard that shows when the readings are correct and assures the dispatcher at a glance that the telemetering unit is in good working order.

When the teletype machine reaches the end of its second line, it automatically turns off its transmitter and all relays return to their home positions, ready for another interrogation.

The equipment now in use by Gulf Interstate is designed to automatically report up to 12 operating functions, should additional data be required. Any function channels that are not being used may be skipped, simply by proper strapping on terminal boards. Thus, the first line shows only three functions in use, instead of the six possible and the other three being strapped out. The second line shows function 05 to be missing. The number 05 is not being used and so is strapped out.

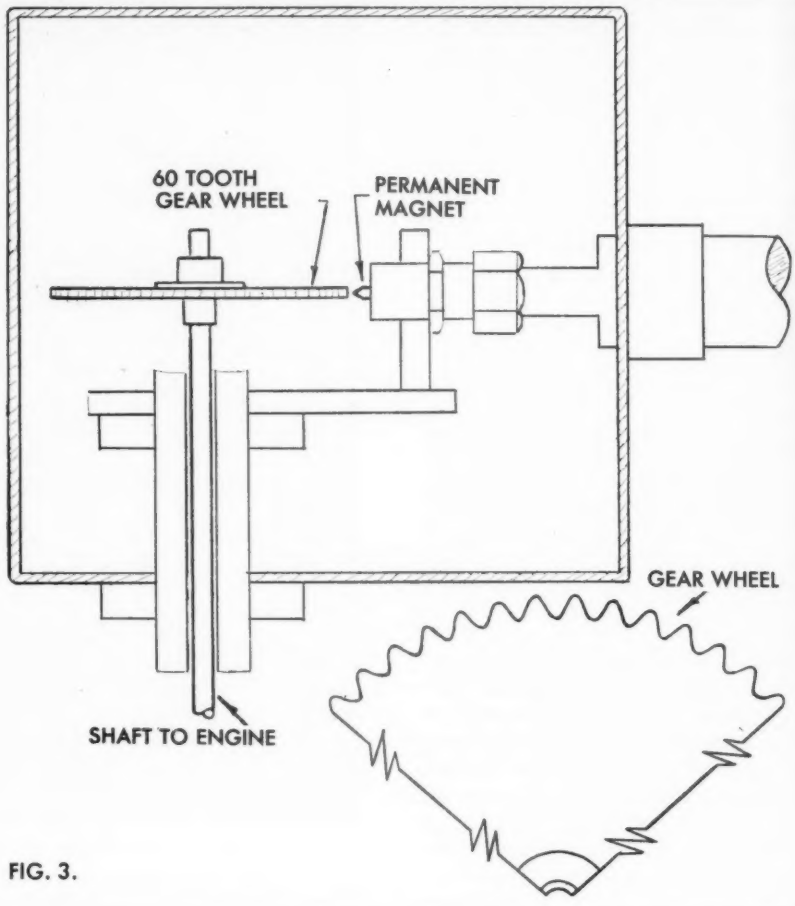


FIG. 3.

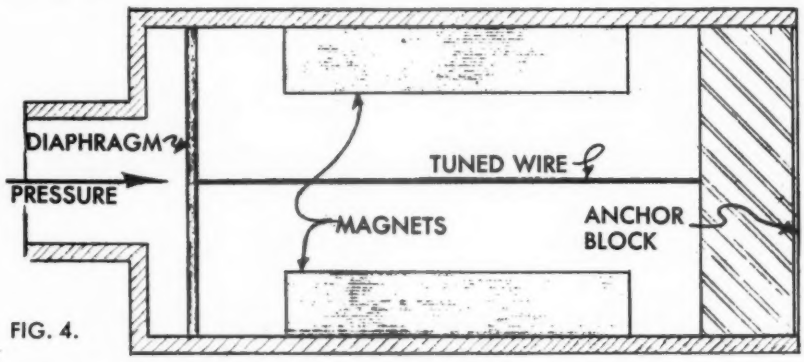


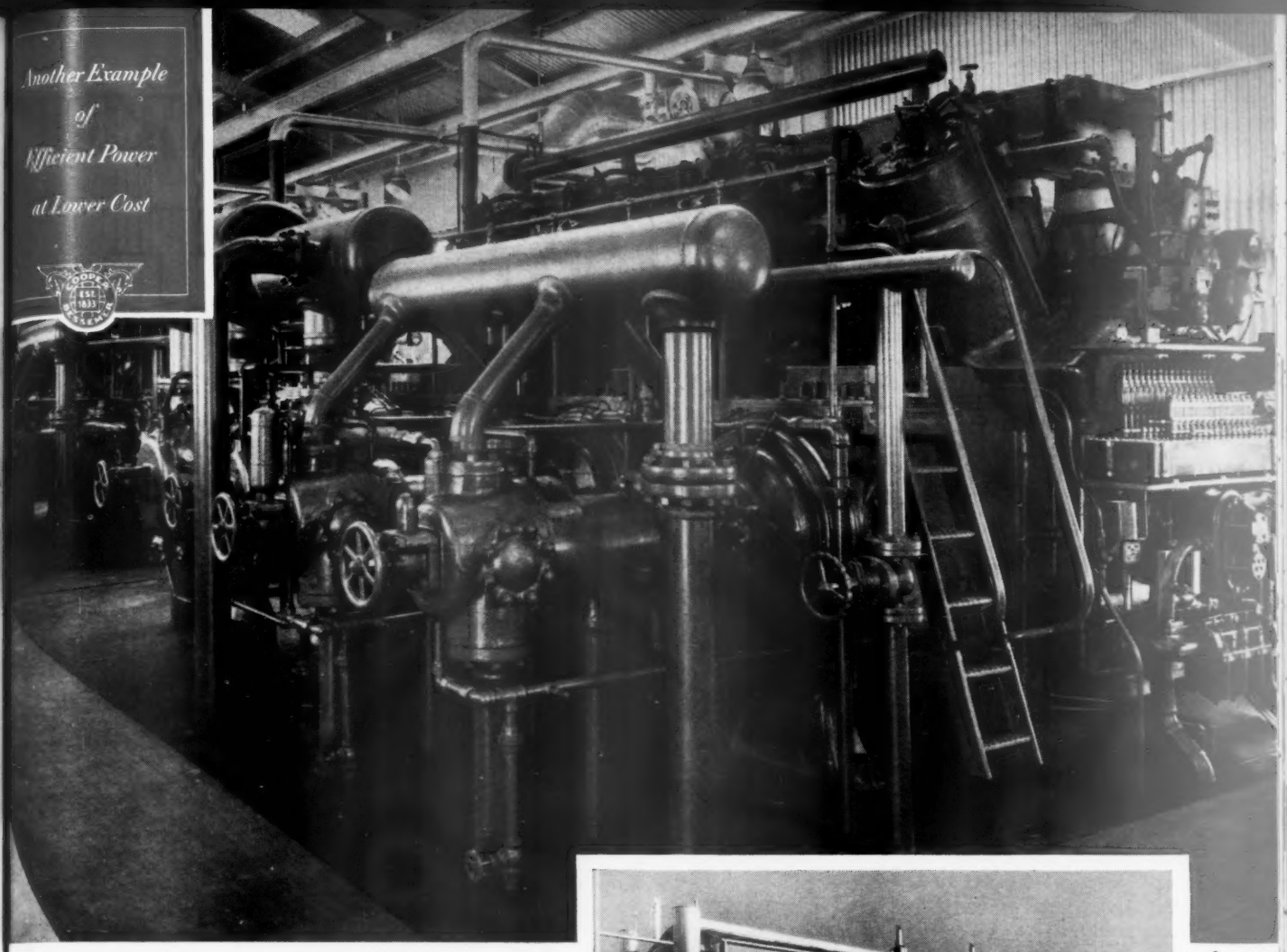
FIG. 4.

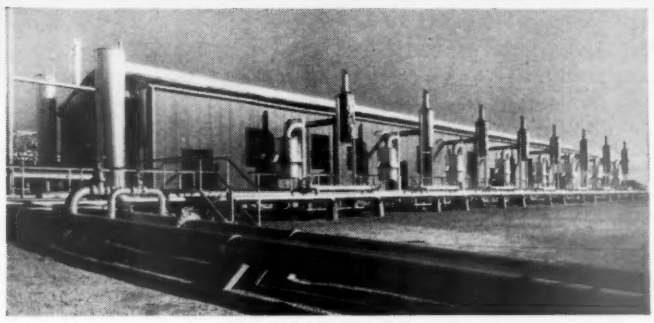
How Transmission Is Made

Having reviewed the form taken by the telemetered data, the next step is to examine the method by which this information is transmitted. There are certain major components necessary to detect the pressures and speeds, measure them, convert them to transmittable form, and make the transmission.

Detection in this case is accomplished by pressure transducers and electric tachometers. (See Fig. 3 and 4.) The transducers, manufactured by the Byron-Jackson Company under the trade name of Vibratron, are the type that produce a frequency output that varies with pressure. The frequency output is actually inversely proportional to the measured pressure. By selecting a proper basic frequency for the transducers, heterodyning this frequency output with a proper fixed frequency, and then reading the difference frequency a result is obtained that is directly correspondent to the pressure. That is, if the pressure is 950 psi, the frequency output to the transducer system will be 950 cycles per second. An example is shown in Fig. 2.

Another Example of Efficient Power at Lower Cost





e-up of eight Cooper-Bessemer 8- and 10-cylinder compressors at llinger, Texas. Two GMV-8-TF's are used for propane refrigeration, d injection, while the remaining six compressors are used for plant ocess gas.

e compact Runnels natural gasoline plant at Ballinger, Texas, contains e Cooper-Bessemer 880 hp GMV-8-TF's, and three 1100 hp GMV-10-'s, totaling 7700 dependable compressor horsepower. The plant was signed by Messrs. F. M. Seibert and W. H. Woods of Runnels Gas.

Dependability plus . in the GMV story at Runnels Gas

YES, efficient, trouble-free performance. That's the experience of Runnels Gas Products Company with the eight Cooper-Bessemer GMV's recently installed at their Ballinger, Texas plant. But that's only part of the story . . . expected and counted on with these modern V-angle compressors.

Runnels Gas, a subsidiary of Union Sulphur and Oil Corporation, uses these GMV's for process gas, propane refrigeration, and gas injection in this new natural gasoline plant of theirs. And they, like so many Cooper-Bessemer customers, have made a point of expressing appreciation for the detailed installation recommendations of C-B service personnel . . . and also for the availability and rapid delivery of needed spare parts. This sort of cooperation is mighty important in *any* kind of engine or compressor application.

Next time your plans call for compressors up to 2500 bhp, check on Cooper-Bessemers.

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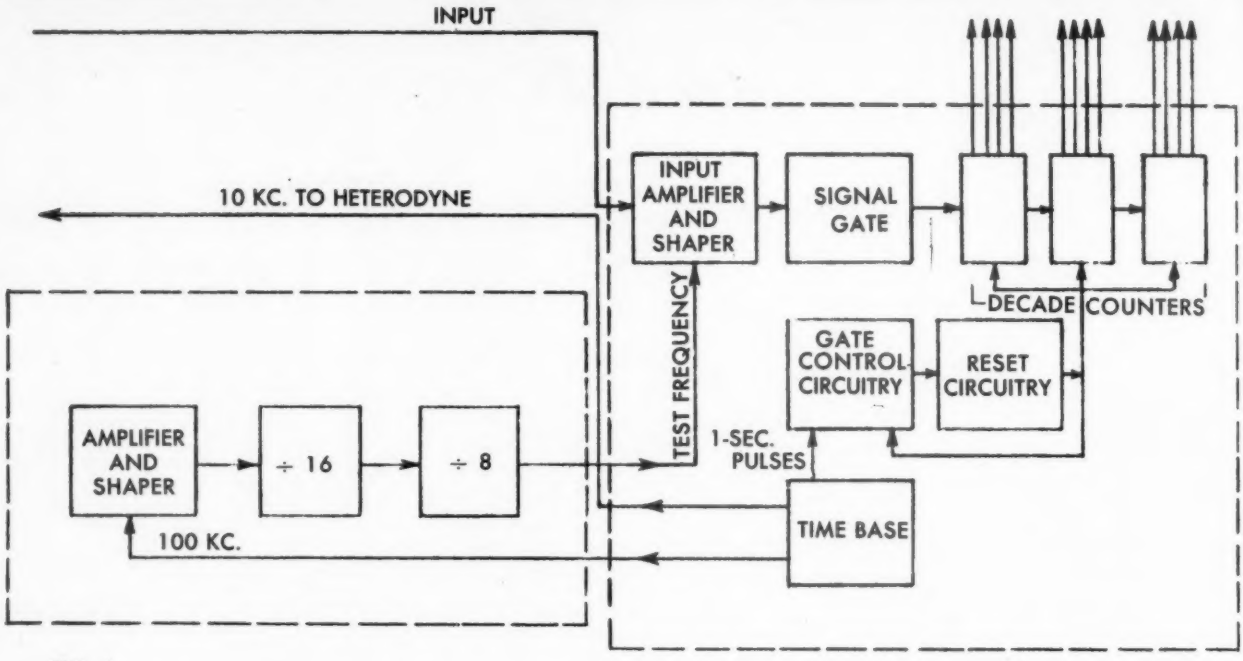
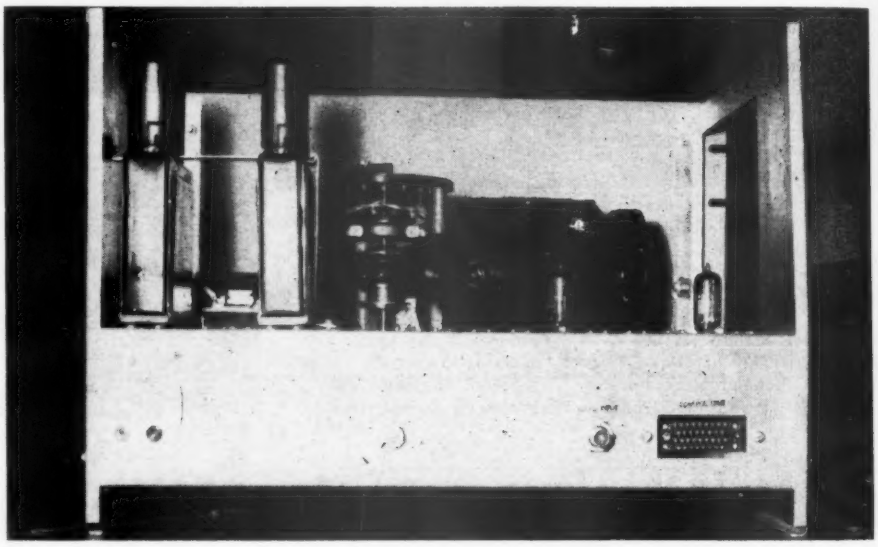


FIG. 5.

At 950 psi pressure, the transducer has an output of 9050 cps. If this is mixed with a frequency of 10-kc, and the difference frequency detected, a reading of 10000—9050 = 950 will be obtained. Again, at a pressure of 550 psi, the transducer has an output of 9450 cps. When mixed with a 10-kc signal it produces a difference in frequency of 550 cps, which is directly correspondent to pressure. The frequency that the transducers will create for any given pressure are set during manufacture and are a rigid part of the design.

The Vibratron units are essentially composed of a vibrating wire in a magnetic field. One end of the wire is attached to a diaphragm exposed to pressure. As the diaphragm moves with changes in pressure, the tension on the wire is changed and the frequency of vibration is altered. This is the frequency that is obtained in the Vibratron output.



This is a rear view of the teletypewriter generator that is used to supply power needed for the transmission of both standard messages and telemetered data over Gulf Interstate's teletype circuit.

Engine Speed Measurement

The tachometers used for engine speed measurement are driven directly by the engines. A toothed gear wheel is rotated in a magnetic field at the engine speed. As the teeth of the gear wheel pass the magnet, a change in circuit reluctance and a corresponding change in field strength is produced. The magnetic field changes can, of course, be made to create pulses in a coil introduced in the field. The number of these pulses will vary directly with the number of teeth passing between the poles of the magnet, and therefore with the rotation speed of the gear wheel.

As the wheel is connected directly to the engine, the number of pulses will measure engine speed. The speed is normally measured in revolutions-per-minute, For practical purposes, however, only a one-second measuring period can be used. (The one minute count would make the telemetering too slow to be practical.) Therefore, if the tachometer can be made to show 60 revolutions for each revolution it actually makes during the one second period, the result will be the number of revolutions in 60 seconds, or revolutions per minute. This is easily accomplished by putting 60 teeth around the periphery of the gear wheel, so that for each revolution 60 pulses are produced. Thus, in one second, the number of pulses for one minute is produced.

The two detector devices—the Vibratron and tachometer—can thus produce outputs that are a function of time (cycles per second and pulses per second), and are measurable by counting device.

Electronic Counter Used

To count the cycles-per-second and pulses per second outputs, an electronic counter is employed. The particular counter used in the Gulf Interstate system is a modification of a Berkeley Model 554 Events-per-Unit-Time meter, commonly called an Eput meter. It is essentially a device that will take

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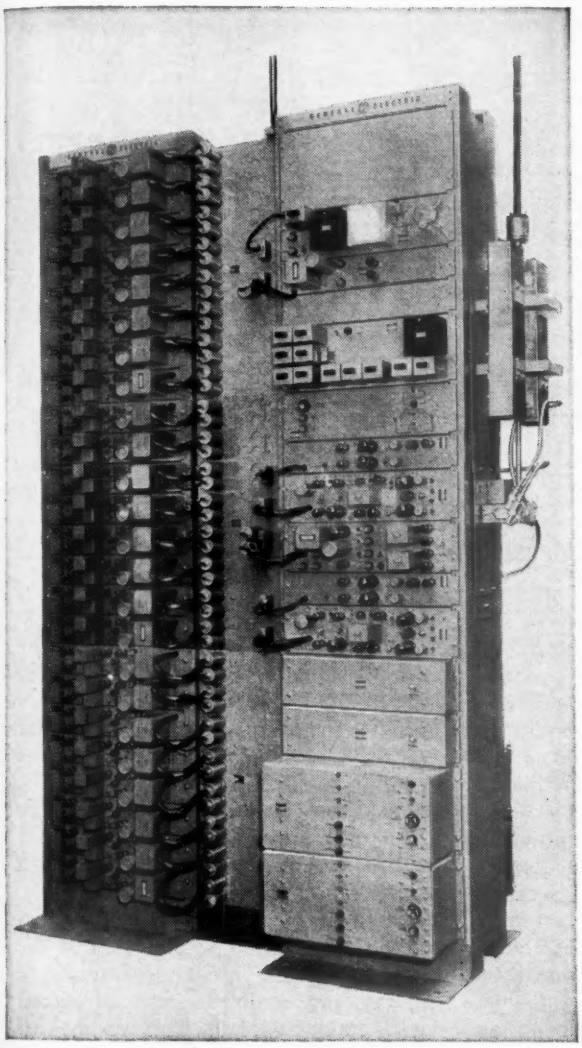
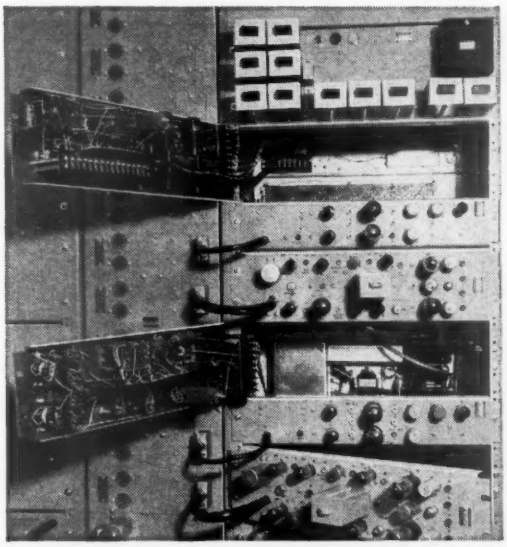


*The new General Electric Quadriphase system utilizes four 9 KC sine waves phased in quadrature for selection of the individual channels.



▲ New ease of servicing—units arranged to slide out or swing out for service or inspection without interrupting operation.

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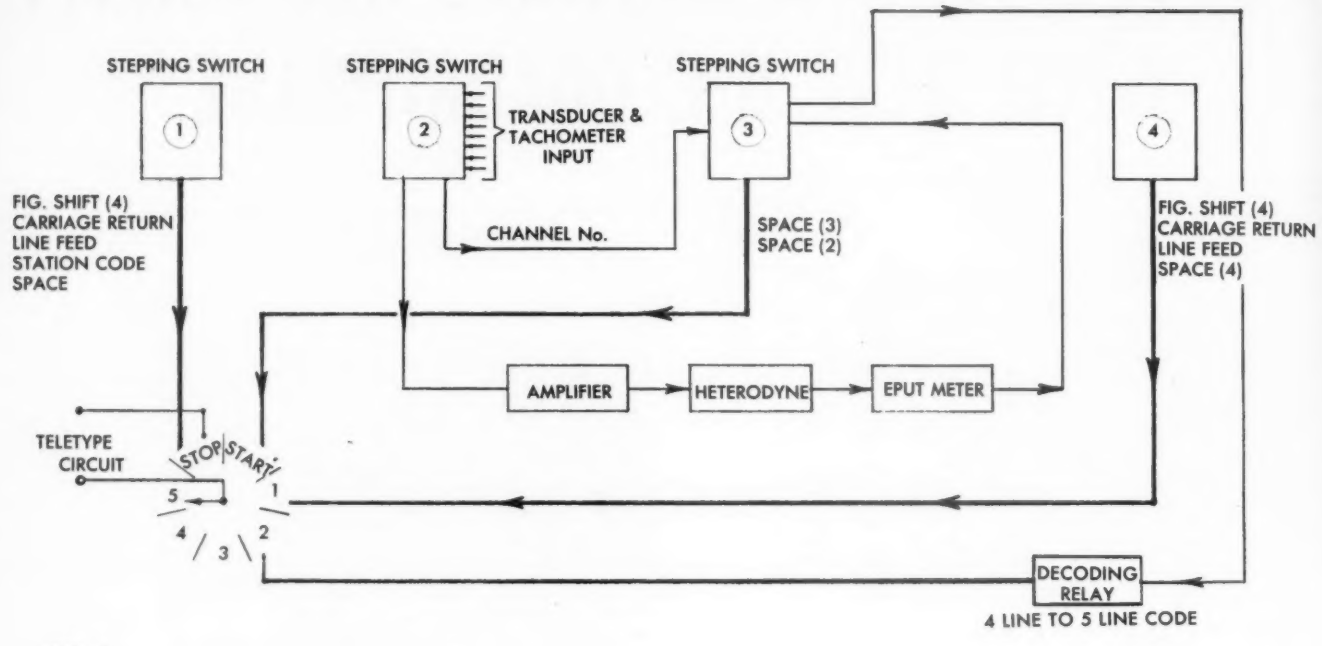


FIG. 6.

an input of detectable electrical occurrences and count the number that take place in a controlled period of time. In this application, the meter will count the number of cycles or pulses that are fed to it in one second. The meter will count these pulses, display its reading in the form of lighted numerals on a series of lucite panels, and then reset itself ready to receive the next set of input signals. Fig. 5 shows a simplified block sketch of the Eput meter and illustrates its basic operation.

The heart of the meter is the time base. This circuit arrangement produces the basic timing frequencies, which insure that the unit counts for only one second. It also produced the check frequency of 781, which was discussed before, and the 10-kc heterodyne frequency that is used to obtain the direct reading transducer output. All functions are controlled from a 100-kc crystal oscillator.

At this point it will help to trace the functions of the Eput meter signal. The signal arrives from the transducers or tachometers as a series of cycles or pulses and enters the shaper-amplifier. Here the pulses are amplified and squared for a cleaner count. They then pass to the signal gate. The gate circuit controls the length of time during which the pulses are passed to the counter units, in this case, one second. The gate in turn is regulated by the gate control circuit, which feeds the "open" and "close" signals. The control circuit is actuated by the carefully controlled one-second pulses produced by the time base generator. When the signal is conducting, the incoming signals pass through it to the decade counters where the count is actually made and displayed. These counters employ binary type circuits and operate in the same fashion as the common binary counter.

The signals from the transducers and tachometers are allowed to pass to the counters for one second. A count is made of the number of incoming pulses and it is displayed on the counting units. The signal gate closes at the end of the one second period, allowing no more pulses to enter. After counting and displaying its reading, the counter must then be reset. The reset feature is accomplished by having the reset circuits triggered by the gate control. The count is allowed to remain displayed for a definite period. The reset then operates on a relay, which ungrounds the counters, causing them to return to their neutral state and preparing them for the next group of signals.

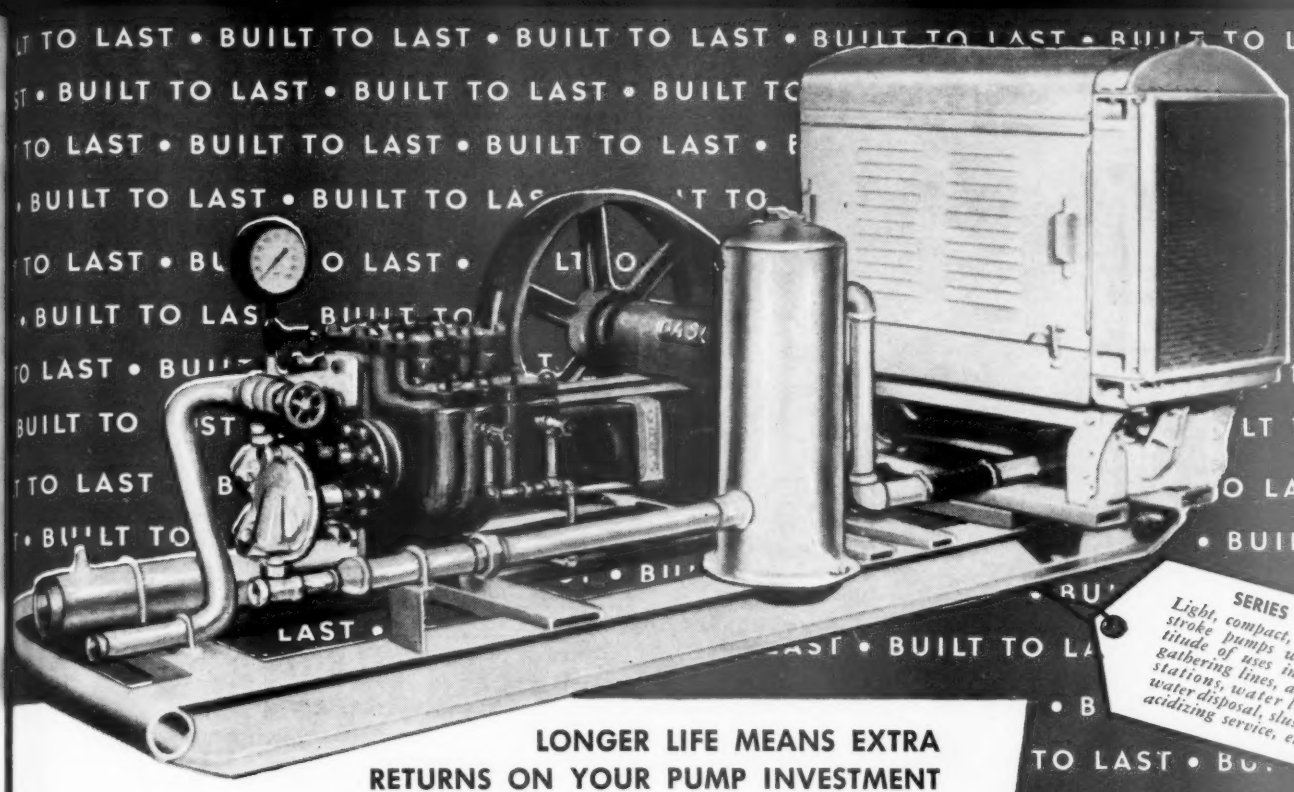
At the end of receiving the first group cycle, the counter is set in neutral and the gate is closed, ready to open for one second and allow the next group of pulses to enter. It is obvious that if the time base oscillators were off frequency, the entire operation would be upset. In order to check this time base with each transmission, the 781-cycle frequency is provided. The check frequency is derived from feeding the 100-kc oscillator output through an amplifier-shaper and then through two divider nets, the first of which divides by 16 and the second by 8. This results in an overall division of the 100-kc signal by 128, giving frequency of the 781.25-cps. Check frequency is fed to the counter in the same manner as any other signal, thus enabling the counter to check itself.

Two functions of the telemetering equipment have now been described: The detection of the variables involved and the measurement of these variables. These two functions would be sufficient if the information were for local use only. However, for Gulf Interstate's dispatching requirements additional steps must be taken. The readings of rpm and pressure appearing on the Eput meter must be converted to a form suitable for transmission and the actual transmission must be made to Houston.

Transmitting the Message

In order to use the teletypewriter circuit and to transmit a message to the teletype machine in the Houston dispatcher's office, the device used must employ the same pulse code as a regular teletype transmitter. The easiest way to accomplish the transition is to actually use a standard teletype transmitter-distributor in the equipment as the transmitting device. To this end, a modified type 14W transmitter-distributor was built into Gulf Interstate's teletype equipment. The type 14-W unit is exactly the same transmitter-distributor as is used in a standard teletype machine. The transmitter-distributor is illustrated in Fig. 6.

The distributor is shown schematical-



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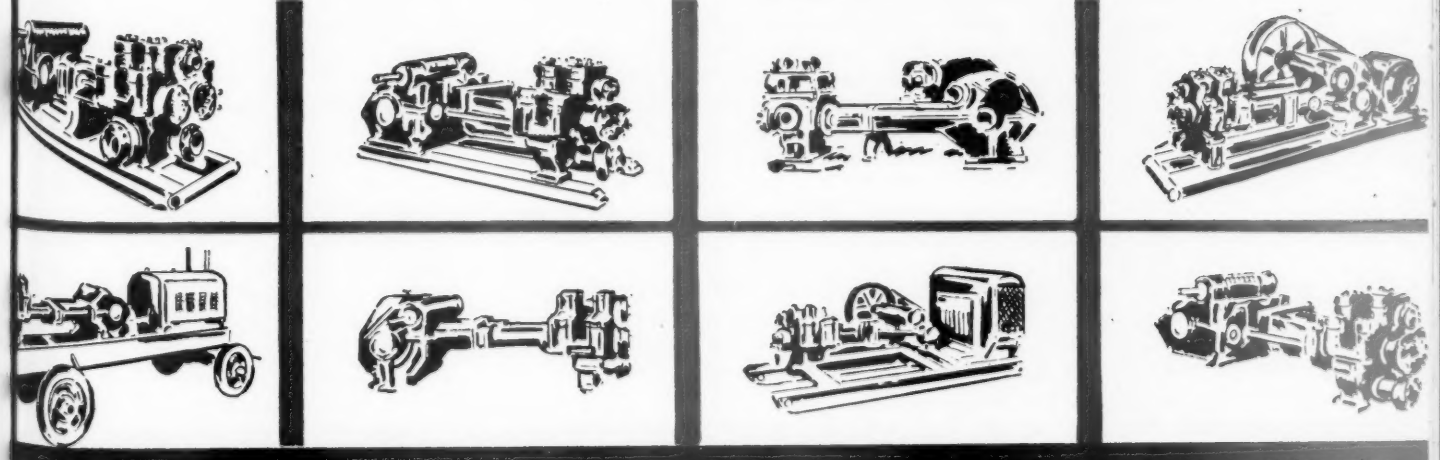

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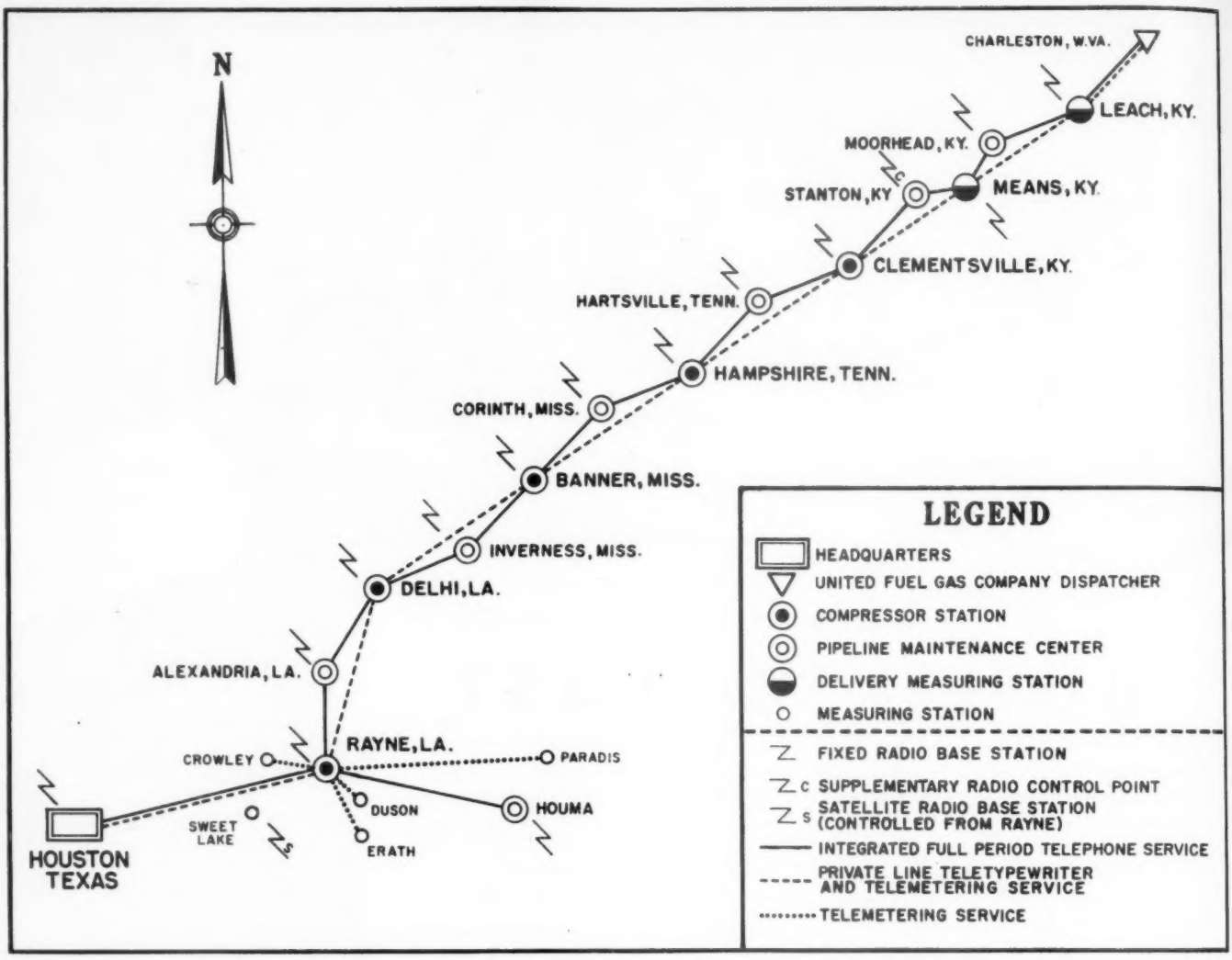


A communications system embracing VHF radio, private telephone line, teletypewriter circuit and telemetering links Gulf headquarters with key points on its 1160-mile pipe line, plus a dispatching office in Charleston, West Virginia, of the United Fuel Gas Company, which routes delivery of the throughput from Gulf Interstate's new system.

ly as a ring made up of seven segments of conducting material, each insulated from the others. A rotating contact, driven by a motor, sweeps over these segments at constant speed. As the brush sweeps over the segments it connects them to the teletype line. If the particular segment over which the brush is passing is energized, a pulse will be sent over the teletype line. On the receiving teletype machine there is an identical distributor that rotates in synchronism with the transmitting machine. Thus, if a segment is energized on the transmitter, a pulse will be sent over the line and received by the receiving distributor as its brush passes over the same segment. On a regular teletype machine, punching a particular key will set up a certain combination of relays, which will cause some segments to be connected to the line and some disconnected. Each key on the board has its own combination, giving different letters or numerals distinct codes.

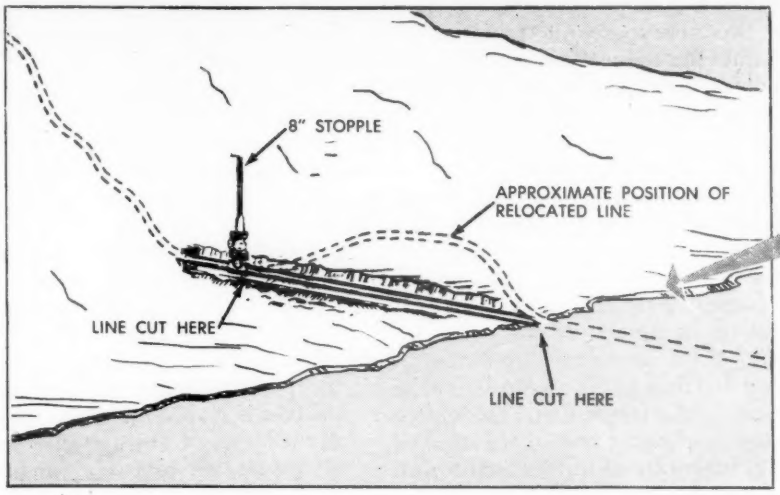
For example, the numeral "8" is transmitted by energizing segments 2 and 3, and leaving segments 1, 4, and 5 clear. The letter "Y"is transmitted by energizing segments 1, 3, and 5, and leaving segments 2 and 4 open. As the pulses are conducted to the receiving distributor they energize the corresponding segments. These in turn cause a relay operation that energizes the proper keys, causing the machine to print. The rotating elements of the transmitter and receiver are kept in synchronization by coded stop and start pulses. Each function that a teletype machine must perform is coded by a combination of the five numbered segments in the same manner described above.

If a relaying system could be devised that would supply the proper code connections to the segments, then the transmitter could be made to send pulses exactly as if a human operator were punching the keys of the standard machine. That is exactly the results achieved in the Gulf Interstate telemetering installation. The keyboard and operator have been replaced by stepping switches and relays.

Relay System Vital Link

The stepping switch and relay system is the equipment that accomplishes the final operations required to make possible the effective telemetering of required data: The conversion of the data to a form for transmission and the sequential transmission of the information in standard form. Reference to Fig. 4 will illustrate how the sequence and conversion is accomplished.

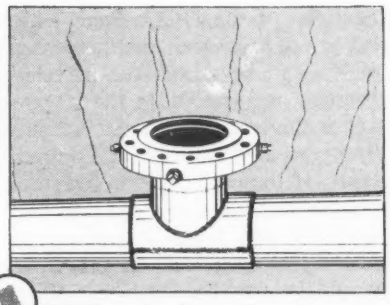
When the Houston dispatcher activates the telemetering equipment, a selector is energized at the particular remote point he has picked. The selector provides a momentary contact closure, which initiates the whole sequence. The teletype distributor motor is energized and any of the stepping



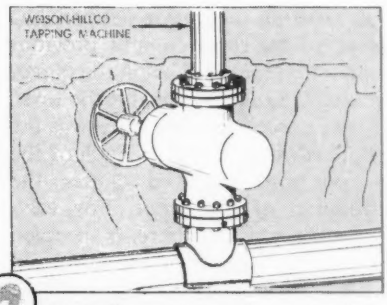
TO facilitate construction of a bridge to span the Lackawanna river, near Scranton, Penna. a major pipeline company relocated a section of their existing 8" products pipeline, using WmSON STOPPLES . . .

PRODUCTS PIPELINE RELOCATED WHILE WmSON STOPPLE* HOLDS 735 PSI. PRESSURE

PROCEDURE



1 TWO 8" flanged split tees were welded to the pipeline on either side of the river.



2 AN 8" tapping valve was then installed on each fitting and taps made at approximately 750 PSI.

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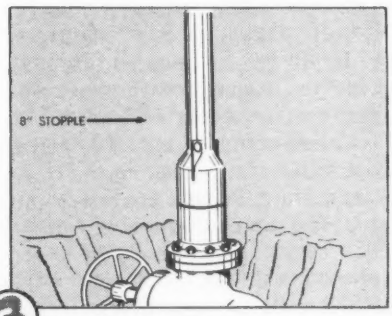
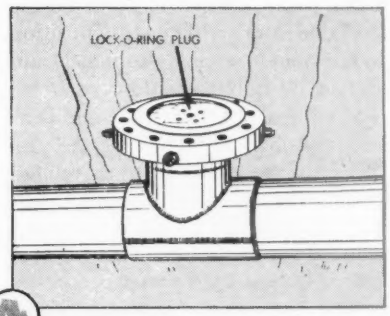


3 8" STOPPLES were then installed on tapping valves, and the line completely isolated by running the sealing element into position, the upstream STOPPLE holding pressure of about 735 PSI.



4 AFTER line was cut, drained and relocation made, STOPPLES were removed and lock-o-ring plugs installed to permit removal of tapping valves. Blind flanges were then installed.

WRITE FOR LITERATURE

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switches not in "home position" return home.

Stepping switch 1 then steps off home to its first position, and readies the transmitter by connecting (through a relay network) the proper segments to the line to cause a *"shift to figures code"*. The signal is transmitted as the brush passes over the particular segments, which cause the carriage on the receiving teletype to shift so that numbers will be printed instead of letters. After the brushes have made one complete revolution and transmitted the code signal, the stepping switch will move to its next position. Each time the brushes reach the "Stop" segment, the switch steps one position. The second position is another *"shift of figures"* code, and the third is a *"carriage return"* that causes the receiving machine to move into position to begin receiving a message, regardless of where it was previously used.

The fourth, fifth, and sixth positions are *"line feed"* codes, which cause the recording paper on the receiving machine to move up one space for each signal, assuring separation between the message to be received and previous messages that may still be on the paper. Positions 7, 8, and 9 transmit the three digit *station code* number. This was the "010" illustrated in Fig. 1. Each of the three positions involved causes the transmission of one digit. For each transmitting station there is a fixed code, which is rigidly strapped in and which will be transmitted in exactly the same form at the beginning of each message. Position 10 transmits a *space* pulse, causing the receiver machine to shift one space, after it has printed the station code number. The tenth position is the last one on stepping switch 1, and it goes to its home position.

The equipment is now ready to identify the channel being checked and to transmit the value of the related function. This is again accomplished by stepping switches, which read the transducer and tachometer outputs measured by the Eput meter.

As stepping switch No. 1 reaches its home position, it triggers switch No. 2, and causes it to step off home to its first position, connecting the first transducer to the amplifier and heterodyne units, and thus to the Eput meter. Stepping switch No. 2 proceeds to go through its sequence of 10 positions. It first codes the transmitter to transmit 3 space pulses. This is a part of the standard spacing pattern of each transmission. As the fourth and fifth positions are reached, the switch is connected to the No. 2 stepping switch, which encodes the channel number as it connects the transducer associated with that channel. Thus the channel number is transmitted. After the channel, two more spaces are transmitted to separate the channel number from the reading. As the stepping switch reaches its next position, it reads the first of the three decimal units, which shows one digit of the actual pressure.

It will be noted in Fig. 4 that part of the output of stepping switch 3 goes directly to the transmitter-distributor, while part of the output goes to the *"decoding"* relay. The space codes are made up of the proper five pulses for coding the five segments of the transmitter and may be fed directly from the switch to the transmitter. The output of the Eput meter and of the channel code numbers need further adjustment, however.

Decimal Counting Units

The Eput meter, as has been pointed out, contains decimal counting units (commonly called DCU's) on which the numbers counted are registered. A particular number stored in one of these DCU's will cause a unique voltage condition to exist on four output connections of the DCU. Each wire will be at one of two distinct voltages, which can be designated as relatively positive or negative. In the 10-pin socket at the base of each DCU, pins 10, 9, 6, and 2 will contain the output voltages. If the numeral 6 is stored in the DCU, then pins 10 and 9 will be positive, and pins 6 and 2 negative. If the numeral stored was 4, pins 9 and 6 would be positive, and pins 10 and 2 negative. In a similar manner, there is a code for each number made up of various combinations of voltages on four wires. The channel number codes are of exactly the same nature.

It will be remembered that the teletype transmitter-distributor requires that five segments be coded. As the four-line output of the DCU and channel codes are to activate the transmitter, an intermediate converter must be supplied to change them from four-line codes. The conversion is accomplished in a *"decoding relay"* network, which will take particular four-line output codes and change them to five-line suitable for transmission.

Again attention is called to the No. 3 stepping switch. It will now transmit the channel code received from switch No. 2, which will go through the decoding relay network to the transmitter, then the two spaces that go directly to the transmitter, and finally the three numerals making up the reading on the Eput meter that go through the relay network to the transmitter. Thus, the reading of one channel is complete. Stepping switch No. 2 will then go to its next position, connecting the transducer, and switch No. 3 will go to its home position and repeat the cycle. In this manner the succeeding channels will be interrogated.

When the equipment has sampled all of the channels that are connected for transmission on the first line of the message (up to six), stepping switch No. 4 comes into service and goes through its sequence. This will code the transmitter properly to cause the receiving machine to receive *shift to figures* codes, a *carriage return,* a *line feed,* and *four spaces.* Thus the machine is moved to its starting position, the paper is rolled up one line, and the unit is spaced for proper alignment of the message. The unit then proceeds to sample the remaining channels in the manner described above.

Testing Equipment

For maintenance purposes, a means is provided to cause the telemetering equipment to go through its complete sequence, with the exception of the actual transmission over the teletype line. By operating a "Test Scan" button on the control panel, the entire operation can be carried out as though the station had been signed by the dispatcher, except that the teletype line has been shorted out and no transmission takes place. Each transducer or tachometer channel may be checked separately by simply pushing a channel test button and then reading the Eput meter for that channel.

Eleven complete telemetering units have been installed on Gulf Interstate's pipe line. To date, operating experience has been very encouraging. The units relay information rapidly. (The transmission shown in Fig. 1 required approximately 30 seconds to complete). The information received is easily interpreted, and most important of all this information is proving highly accurate. On a 96-hour test run, in which the readings were transmitted to Houston once each hour and there compared with readings made with deadweight gage by an operator, the average difference was only 0.12 per cent of the deadweight reading. This difference is less than the accuracy expected of a deadweight reading, indicating that these instruments may be more accurate than the standard to which they are normally compared.

The successful operation of the telemetering system to date indicates that it will fulfill all requirements for accuracy, speed, and reliability. At the same time, maintenance experience has been highly satisfactory. There is reason to believe that the telemetering system will continue to serve an important role in Gulf Interstate's operations, and will help make those operations more efficient and economical. * * *

New aerial survey product saves time and money

PHOTO-ALINEMENT MAPPING Provides Complete Record

John C. Bayless*

SOMETHING HAS BEEN ADDED TO THE mapping technique for locating pipe lines, planning for construction, and maintenance.

The new technique is in the family of aerial survey products. Its features open up a new and increasingly important field of highly useful and efficient alinement maps and drawings for the pipe line industry. These maps require the minimum of drafting time but result in the most usable operational drawing and field map yet devised.

Today, the maps for locating a pipe line and preparing plans go far beyond the old concept of route surveys. In earlier times, several field parties surveyed trial lines, but now all possible routes are worked out and compared in the office, with substantial savings, by the full use of photo-alinement maps made from aerial photographs. Engineers, survey crews, and draftsmen are not diverted from their primary function of design and layout. The best route for the line is determined before a single stake has been driven and, in addition, design engineers have the benefit of the best knowledge of the terrain surrounding their projects.

Photogrammetry has been used for many years in pipe line surveying, but here is an example of how the best from aerial surveying has been combined with the best elements of conventional alinement sheets to simplify field surveying, decrease drafting time, and produce an ideal base map to record preconstruction and construction surveys and alinement.

Aerial photographs do not eliminate all ground surveys. They must be oriented and controlled by measurements from previously measured lines, section corners, or bench marks that are usually available within the engineers' office or from existing county and topographical maps. Once oriented, the photograph becomes a map on which is recorded the most complete inventory of natural and cultural detail available.

At all stages of engineering, there is a need for reliable quantitative data that can be obtained more accurately and economically by examination of aerial photographs and photo-alinement maps. The engineer with only a basic understanding of the characteristics of photographs can gather this data and pinpoint best locations for difficult kinds of work by use of engineer scales and a three-dimensional view of the photographed earth surface through a stereoscope. By careful use of parallax measuring devices, even spot elevations can be determined. The information obtainable from a single stereo-pair of photographs in the office is considerably more than that gathered in the field in a comparable period of time. Thus total engineering costs are reduced.

The average scale of an aerial photograph is easily determined by the ratio of measured ground distance to distance on an aerial photograph. If distances on the ground are unknown, the average scale may be obtained by dividing the flying altitude above average ground elevation by the focal length of camera lens. This relationship and equation is shown in Fig. 1. The scale will determine the area shown on standard 9-in. by 9-in. aerial photographs. In most planning phases the effect of tilt of the camera while in flight can be ignored. Reliable aerial surveying firms deliver photographs that have tilt of less than 5 degress. Greater amounts will produce definite errors in measurements.

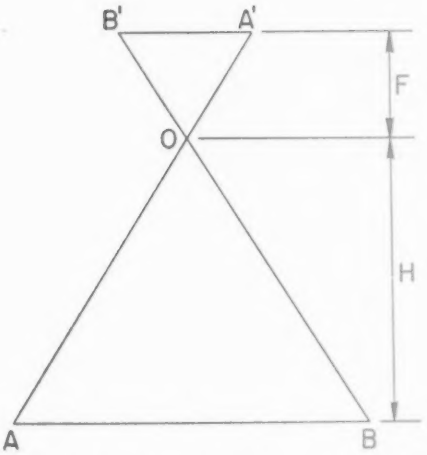

FIG. 1. Fundamental relations in photograph scale

O = lens of aerial camera
F = focal length of aerial camera in inches
H = altitude of camera above terrain in feet
AB = position of 2 points on ground in feet (ground distance)
B'A' = photographic image of ground point A&B on negative (print distance) in inches

From similar triangles

$F : B'A' :: H : AB$

$F\ (AB) = H(B'A')$

$$\frac{H}{F} = \frac{AB}{B'A'} = \text{scale of photograph (feet per inch)}$$

Engineering studies are primarily concerned with ground conditions and, therefore, photographs should be taken before vegetation is in leaf. Fortunately, this is also a time when moisture conditions are near maximum and dark tones tend to indicate areas of high moisture content and poor drainage as shown in Fig. 2. The ideal time to photograph pipe line routes for engineering studies is late fall or early

*Oil industry operations, Abrams Aerial Survey Corporation, Lansing, Michigan.

EXCLUSIVE

▲ FIG. 2. Pipe lines following a railroad and highway through areas of swamps and abandoned crescent-shaped river channels now filled with water and vegetation. Scale is 1 in. equals 1000 ft. Poorly drained areas appear dark. Man-made features resemble their conventional map symbols. The railroad appears as dark narrow band with large radius curves. Roads have sharper curves. Pipe line ditch scars are light bands across the bottom of the photograph.

spring although the urgency of work often demands photography during other seasons in the year.

Preconstruction aerial photographs will eliminate many field trips. A comprehensive photographic interpretation of large areas can result in avoiding areas requiring excessive excavation of bed rock, unstable areas, or large areas of seeps or swampy ground. The new field studies that will be necessary can be directed with better efficiency. Extensive use of aerial photographs by survey field parties is a great assistance in establishing a final surveyed line.

One of the greatest advantages of aerial photographs is the area perspective obtained from assembling individual prints into a composite picture map, or mosaic. A simple type is the semi-controlled mosaic assembled by matching detail of the overlap areas on each photograph within a flight line and the side lap areas of adjacent flights. The photos are trimmed along fence lines, roads, woods, and other features that tend to help match the cut line with adjacent detail. It may not be necessary or desirable to correct photographs for minor tilt and distortion, because only the accurate central portion of each photograph is used.

A highly efficient reproduceable photo-alinement map has recently been introduced. Here is a typical mapping procedure.

Photographic planes fly the area of the preliminary proposed route between terminal points and principal intermediate objectives. Small-scale photographs are taken with a Bureau of Standards approved precision topographic camera. A scale of 1:20,000 in rural areas and 1:12,000 in urban areas has proved satisfactory.

Photographs are taken to rigid specifications. The broad area photographed is examined stereoscopically by the pipe line location engineers and all the feasible routes determined. The preferable route is selected by comparison of the routes on the photographs supplemented by checks on the ground at sites of difficult or special problems. The objective made possible by preconstruction aerial photographs is a route of minimum length that approaches a straight line with proper consideration for accessibility, overall construction costs, and future operation and maintenance requirements. High-cost right-of-way situations can be avoided by routing around valuable cultivated areas, buildings, other pipe lines, and similar items.

Trained photogrammetrists prepare semi-controlled mosaics to show pictorially the pattern of land use and the principal topographic features. The prints used have been brought to a common scale in the photographic laboratory and are cemented to a semi-rigid backing. Orientation is maintained by reference to ground survey data to assure accurate distance and azimuth measurements.

The mosaics become base maps when copied to uniform sheet size on high-resolution matte surface film with a dimensionally stable, flexible and durable base. The matte, or translucent surface, allows pencil and ink drawing to define the "as staked" locations, planimetric detail, and land ownership along the proposed right-of-way. Marginal data and outline can be added.

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M-25
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26" NO. 2
M-25
M-25
114+2212 R
113+2616 ℄ Rd.
Greenville Municipal Airport
30" Tenn. Gas T
113+5010
8" Wld.
4"
8"
114+46
114+243 Wld.
8" Tie-over Line
3/8"
26" x 1/2" A.O. Smith
3/8"
26" x 9/32" A.O Smith
26" x 1/2" A.O.S.
113+968
113+1168
113+1322
113+1489
113+1632
113+1826
30"
26"
24"
30"
113+5256
A.O. Smith
113+5264
114+46
PL-1516
PL-1517
114+76
114+88
114+108
A.O. Smith
4+116

FIG. 3. PHOTO-ALINEMENT MAP. A small section from a 24 by 36-in. sheet with a sample from the corresponding pipe line construction data. Scale is 1-in. equals 1000 ft. This type map may record preconstruction or as-built alinement which has been drafted on the base map copy film of an aerial mosaic. The usual office copy is made on blueprint paper or a dry development paper. Marginal data may also include a land ownership record.

Prints of the films produced by blueprint, Ozalid, or Bruning process are photo-alinement maps ideally suited for planning, design and maintenance.

Temporary notes can be drafted in pencil on the translucent film surface to produce progress maps. These are used very effectively by the survey parties as preliminary maps that go far beyond the limits of survey notes. Photo-alinement maps are particularly useful in staking locations in congested urban areas.

This system of low-cost, reproduceable photo-alinement maps is largely replacing planimetric maps in some companies. The greater usefulness of photo-alinement maps is illustrated by Fig. 3, an example taken from a standard sheet of the Texas Gas Transmission Corporation. In the words of J. E. Thompson, supervisor of mapping and surveying for Texas Gas Transmission, photo-maps "... furnish all the information given by the latter, plus a great deal more in the pictorialization of the country itself, with its topography and culture in complete and accurate detail."

The total cost for aerial photography, mosaics, and reproduceable intermediate films for photo-maps is about $25 to $35 per line mile, and in some cases may be much less. At a scale of 1-in. equals 1000 ft, a single flight line provides about three-quarters mile coverage on either side of the pipe line.

Preconstruction aerial surveys avoid re-routing situations often necessary when available maps do not show all up-to-date detail. On a relatively short, 32-mile, 14-in. gas line built by Ford, Bacon and Davis for Michigan Consolidated Gas Company, the cost of the entire survey was saved several times in the direct cost of pipe saved, not to mention additional costs avoided by routing around a lake and bog area that would have been very expensive to cross. Another advantage of this preconstruction survey was that weights needed for river and swamp crossings were computed and ordered in advance.

The reproduceable photo-alinement maps recently made for the Hardensburg-Bedford-Columbus Line of Texas Gas revealed a man-made lake not shown on existing maps. Texas Gas engineers consider that this preliminary aerial survey will save the cost of one ground survey in addition to having twice the use value of a ground survey. Further, they expect like others, to obtain lands for the right-of-way immediately after plotting the center line on the photo-maps and before the ground survey begins.

Right-of-way agents find reproduceable photo-alinement maps are of great assistance in determining land values, severance damage, in location of buildings and cultivated land. Supplied with these maps, agents begin obtaining easements before property owners have been disturbed by ground survey parties. During and after construction, agents who are well informed from photographs can better assess damages that may result from the pipe line and, by careful explanation to the land owner, obtain a suitable settlement out of court.

Large scale photographs, or photographic enlargements to an exact scale, are useful where a larger image size is desired. Major installations such as compressor and pumping stations, and terminal facilities are often reproduced at a scale as large as 1-in. equals 40 ft. Some pipe line companies have the right-of-way photographed at a scale of 1-in. equals 2000 ft in rural areas and 1-in. equals 200 ft in urban areas. Two diameter enlargements, 18-in. by 18-in. with 60 per cent overlap, are then prepared at scales of 1-in. equals 1000 ft and 1-in. equals 100 ft for stereo-examination.

When accurate ground elevations are desired, topographic maps can be made from the original pipe line survey negatives. Photogrammetrists make vertical and horizontal measurements for engineering planning which comply in every detail with National Standards of Map Accuracy. The methods of compilation of topographic maps from aerial photographs and the related equipment have been tested for years. Today, these maps can be as good as, or better than those made by conventional methods, and result with a reduction of up to 50 per cent in overall cost.

The newest first-order stereo-plotting instruments in use are manufactured by Officine Galileo in Florence, Italy. These are very fast and economical instruments well suited for larger scale, small contour map compilations, and extensions. For regional reconnaissance, these Italian instruments can be used to draw 20 ft contour interval maps that meet standard map accuracy and standard map content from 1:60,000 to 1:70,000 scale photographs. For engineering planning, larger scale photographs yield mapping scales of 1-in. equals 50 ft and 1-in. equals 100 ft with contour intervals of 1 and 2 ft which are accurate within 1 per cent on the horizontal scale and approximately 1 foot on the vertical scale.

The cost of a topographic map with a 5-ft contour interval is approximately $600 to $1600 per square mile at a scale of 200 ft per inch. Ground control is usually a separate item supplied by the contractee. The cost of maps depends upon the type of terrain, planimetric detail required, and the size of the area to be mapped. Maps at a scale 1-in. equals 100 ft with a 2-ft contour interval may cost as little as $1200 per square mile in large tracts. In most cases, the cost of such photogrammetrically compiled maps is much lower than that done by field surveys and can be completed in as little as one-fifth the time.

Accurate plan and profile drawings are frequently prepared to show the centerline and elevations along the pipe line routes. Profiles have been particularly useful in determining hydrostatic pressures during hydraulic testing of gas transmission lines. Profiles prepared photogrammatically usually cost less, particularly when large scale photographs were previously taken for photo-alinement maps.

Additional savings are now being realized as pipe line contractors have come to appreciate that accurate information furnished on photo-alinement maps permits the most economical use of equipment and eliminates the uncertainties of bidding. Contractors have shown an increasing interest in aerial photographs for locating access roads and equipment dump sites. In at least one case, a pipe line contractor has used an independent aerial survey as a basis for court action in his claim for an adjusted fee.

An almost standard practice is to re-photograph pipe lines after construction to provide a complete record map of where the line actually was ditched. Control for the mosaics is effected from the location survey for the pipe line. An inexpensive lens stereoscope is sufficient to reveal block valve and blow-off locations using 1:12,000, or 1-in. equals 1000 ft scale photography. Reproduceable "as built" photo-alinement maps are cheaper and more accurate because draftsmen work with fewer symbols and scales. Obscure property descriptions are easier to reconcile to natural features and survey notes are easily checked for obvious errors.

Most companies store original mosaics for future reference. All permanent drafting is done on the intermediate copy films, including tabled land ownership data and construction histories. Any number of up-to-date photo-alinement maps are then inexpensively reproduced at any time for all departments concerned. * * *

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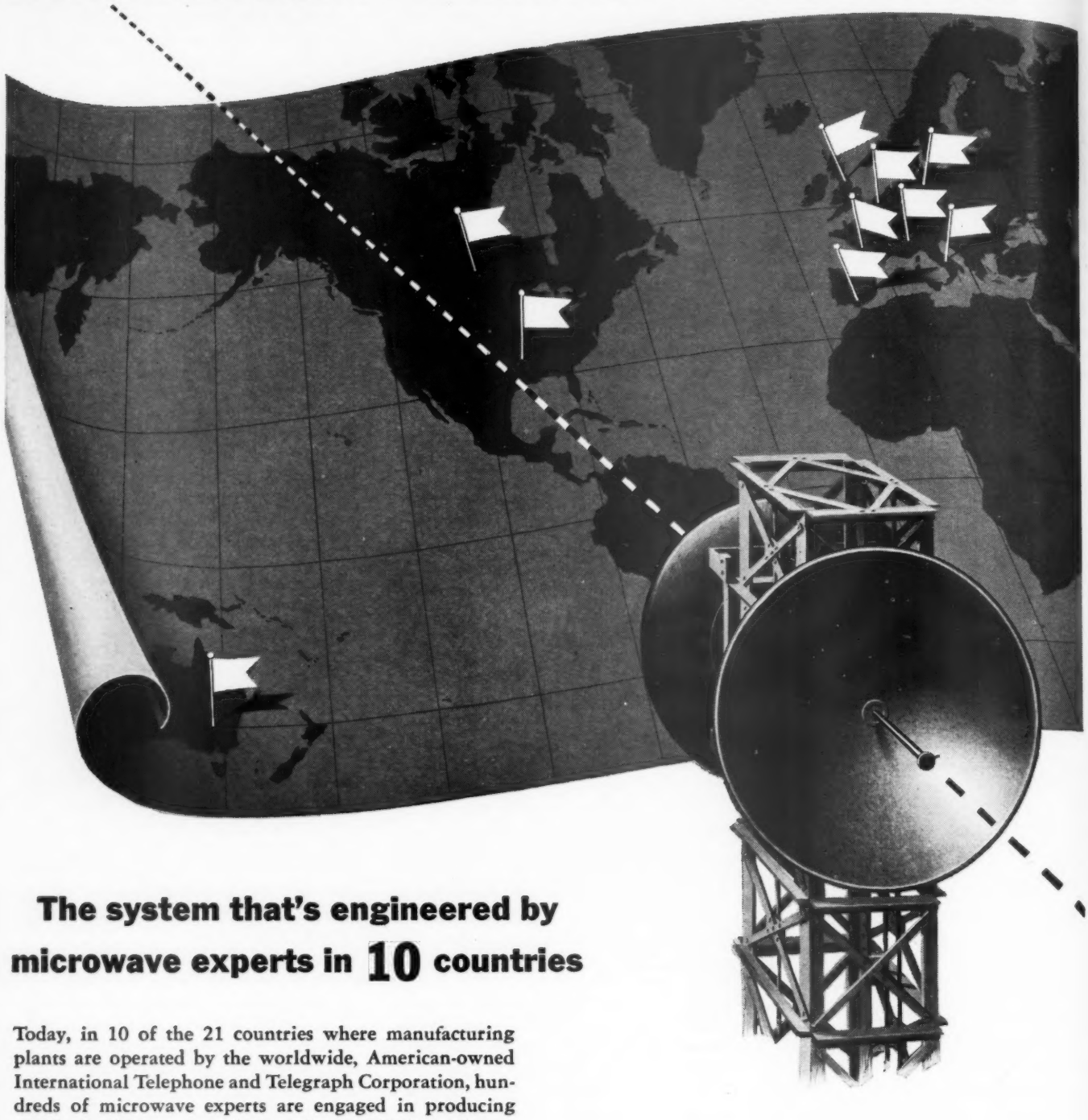

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PIPE LINE COMMUNICATION & CONTROL

Lee Elmore

THIS new monthly feature of *The Petroleum Engineer* is addressed specifically to pipe line communication men, management, and operating men interested in efficient operation and control of pipe lines.

Communication and control is important in protecting the heavy investment in facilities and in economically directing the flow of transported products. The past few years have seen major strides in the communication art, and the present evolution in automatic control promises even greater changes during the next few years. Microwave, pioneered by the pipe line industry, is now well established and offering ready-made channels for additional purposes such as control, centralized accounting, and extended mobile radio coverage.

The monthly section on *Communication & Control* will help keep you abreast of significant innovations and keep you posted on what other companies are doing with new techniques in the solution of their problems. Topics will be covered briefly, and will be supplemented by comprehensive articles carried by *The Petroleum Engineer*.

Coverage will broadly follow the application of electronics to the communication and control needs of the pipe line industry. Topics will include microwave, carrier, mobile radio, industrial TV, supervisory control, teletype, automation, data transmission, etc. Installation highlights, operational data, and engineering notes will be included, relying on photos and charts to replace the proverbial 1000 words each. Emphasis will be on dollars, db's and efficient pipe line control. Your comments and news items are invited.

EXCLUSIVE

PIEA-PESA Show Highlights

Pipeliners and communications equipment dominated the Shamrock in Houston, Texas, April 20-22, in the biggest annual get-together of petroleum communications users and suppliers. The 1955 conference attracted 930 members of the Petroleum Industry Electrical Association and Petroleum Electrical Supply Association and an uncounted number of guests. Dominant among the many PESA exhibits and PIEA sessions was microwave communications. Considerable attention was also devoted to supervisory control, mobile radio, and corrosion.

Outstanding speakers at the conference included Colonel Edwin L. White, Chief of the FCC Safety and Special Radio Services Bureau, who discussed the Commission's recent government-industry conference on rules for microwave and the Commission's proposal to split the mobile radio channels. Joseph E. Keller, PIEA general counsel, reported on developments in Washington and elsewhere during the past year as they affect microwave and mobile communications in the petroleum industry.

The exhibition of multi-channel microwave equipment topped any show thus far. Eleven manufacturers demonstrated their latest microwave and multiplex gear.

Recently unveiled equipment included a new pulse-position-time system and a hetrodyne relay system designed for operation in the new 2450-2700 mc band. Also new was a 6700 mc, 7-channel system in a weathertight package for pole mounting or outside locations. Of particular interest to management was an exhibit of data transmission for centralized office accounting over microwave. One exhibit included a display showing use of a 20 by 24 ft passive reflector or "billboard" located 1.2 miles from a terminal for bouncing microwave beams on to a far terminal 20 miles distant. Supervisory control of pipe lines over microwave was highlighted by another exhibit, using an existing pipe line system for illustration.

Four high capacity single sideband multiplex systems were shown. Three of them are designed for 120-channel operation, the fourth for 72-channel operation. One of the 120-channel systems is unique in its use of printed wiring boards and mechanical filters. Another features plug-in compandor units for providing up to 22 db improvements in voice circuit quality. The other two high density systems also utilize single sideband techniques.

Microwave User Experience

The panel discussion on microwave at the PIEA-PESA show provided an inside look into microwave system performance by "asking the man who owns one," in this case, the pipeliners who operate major microwave communications systems.

Moderator for panel session was Chester Upson of Texas Illinois Natural Gas Pipe Line Company, who, in turn, called on panel members representing seven companies operating nine microwave systems ranging up to 1400 miles in length. These microwave users reported on system performance, operational reliability, maintenance problems and cost factors relative to RF and multiplex equipment, structures, power plants, and vacuum tubes. Problems were discussed in a forthright manner, and the concensus was highly favorable toward use of microwave for pipe line communications. Highlights and vital statistics are tabulated below:

Overall reliability: Up to 99.2 per cent for 400 mile systems.

Voice Channel Quality: Signal-to-noise ratios of 40 to 65 db.

Receiving Tube Life: 10 to 12 months for home receiver types.

Transmitter Tube Life:

Type	Description and Use	Life
5976	Reflex Klystron—6700 mc	4-5 years
X26D	Reflex Klystron—6700 mc	12 months
2C39	2000 mc triode	7-9 months
2C43	2000 mc triode	3-4 months or less

The use of companders on several

systems proved to be an economical means of buying an additional 13 to 20 db in voice circuit quality. Difficulties were reported with several receiving tube types including the 6AK5, 12AT7 and 6AH6. Reports of individual members are summarized below:

Bob Buttner of Transcontinental Gas Line, indicating a general unhappiness over use of home-set receiving tubes, reported that 45 per cent of their outages were due to weak tubes.

Jim Fowler of Panhandle Eastern Pipe Line, discussed the RF operation of their 400-mile microwave system. Overall reliability was 99.3 per cent in 1953 and 99.2 per cent in 1954. Less trouble is experienced on the microwave than the wire line facilities. The 0.8 per cent outage in 1954 was caused by 35 failures totaling 69 hours outage. Thirty-five per cent of this outage time was due to tube failures. Fowler reported troubles with 12AT7 and 6AK5 tubes that led to aging of the latter type for 48 hours with a resultant 40 per cent reject rate. Life of Type 5976 klystrons has averaged 25,000 hours with the lowest being 22,000 hours. Thirty-five per cent of the klystrons installed in 1952 are still operating. Power supply failures were reported as a result of inadequate multiplex fusing. The Panhandle maintenance schedule is a monthly visit with a full check every 3 months. The voice circuit signal-to-noise ratio is 45 to 65 db over the 400 mile system. The 6700 mc system is not bothered by propagation fades.

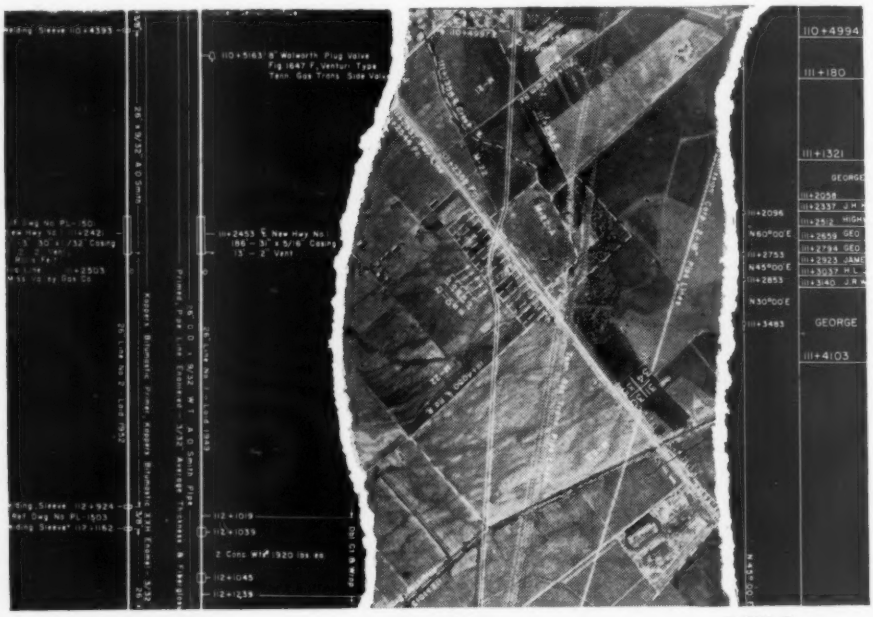
Bill Lancaster of Sinclair Pipe Line, reported on the multiplex and operational aspects of three separate microwave systems. His 400-mile, 24-channel system provides 99 per cent overall reliability with a voice channel signal-to-noise ratio of 40 db. Addition of companders provided a 13 db improvement. The second Sinclair system, a 12-channel system in operation for one year, provides 99 per cent operation and a signal-to-noise ratio of 55 db. The third system, also 12 channels, provided 98 per cent utilization and a signal-to-noise ratio of 55 db. This latter system employs an objectionably large number of tubes and displayed trouble on party line operation.

Max Johnson of Texas Illinois, reporting on structures, recommended a separate room for auxiliary power generators. Tower lamps are changed every six months for $33 per year for each tower. A three man tower crew is employed full time on this 1000-mile system, and cathodic protection is provided for towers and anchors.

Fred Jones of Platte Pipe Line, reporting on primary and auxiliary power sources, recommended exercisers for standby power generators. The power bill per station was indicated as $20 to $35 per month.

Ed Dunn of Keystone Pipe Line, provided a useful survey of tube life and cost. The cost of replacing a $3 tube is approximately $25. Receiving tube life in 10 to 12 months, and a complete change of tubes is made each year. 6AK5 and 12AT7 troubles were reported; A survey by Dunn of pipe line microwave operators revealed a transmitter tube life expectancy as tabulated above. This data indicates the type 5976 klystron is the most reliable microwave transmitter and provides the lowest annual tube cost.

L. R. Thomas of Santa Fe Railroad reported on the high-low antenna technique for over-water propagation paths. He also warned that tree growth can affect path clearance and performance. Of the 20 type X26D klystrons in his system 18 were replaced in two years. The signal-to-noise ratio of 40 db was increased to 60 db by the addition of companders. A weekly station visit and tube check every 90 days have resulted in negligible outages. Replacement parts for his system total $75 to $100 annually per station. * * *



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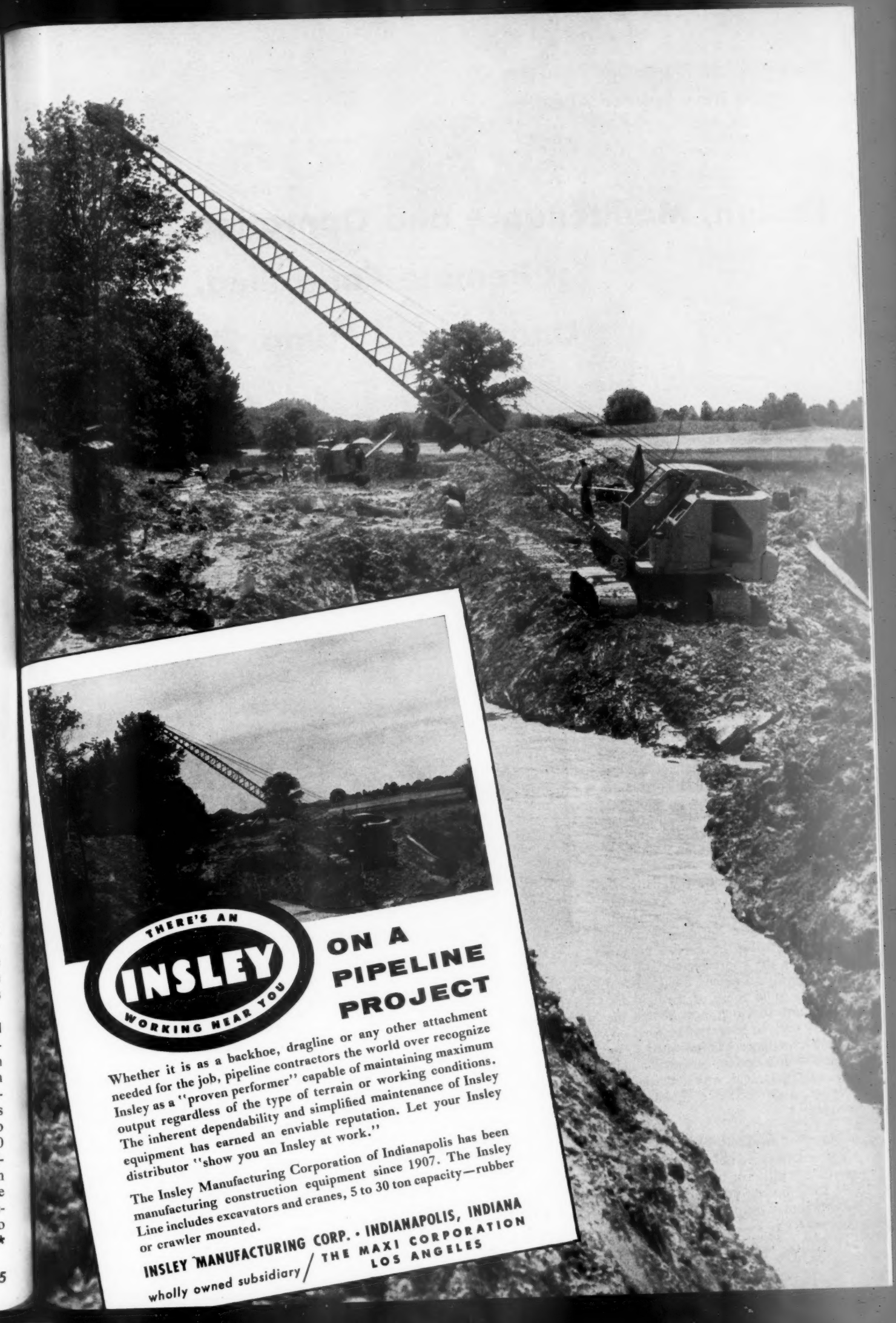
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Here's What Plantation Pipe Line Engineers Have Learned About the

Design, Maintenance and Operation of Remote-Controlled, Unattended Pump Stations

FIG. 1. Aerial view of McGaw pump station, near Athens, Tennessee, shows station layout, microwave tower in foreground

T. V. Bockman
R. S. Cannon

WITH AN EVER-INCREASING PERCENTage of his time spent trying to make an equipment layout that will be proof against any possible error that the operator at an attended station can make, the design engineer can hardly be blamed for wanting to try out an unattended, remotely controlled station. Operating experience with a few unattended stations probably will dampen his enthusiasm somewhat, at least to the point where he is willing to admit that there is still enough development work required on such stations to preclude any immediate rush to put the entire pipe line industry on a remotely controlled basis.

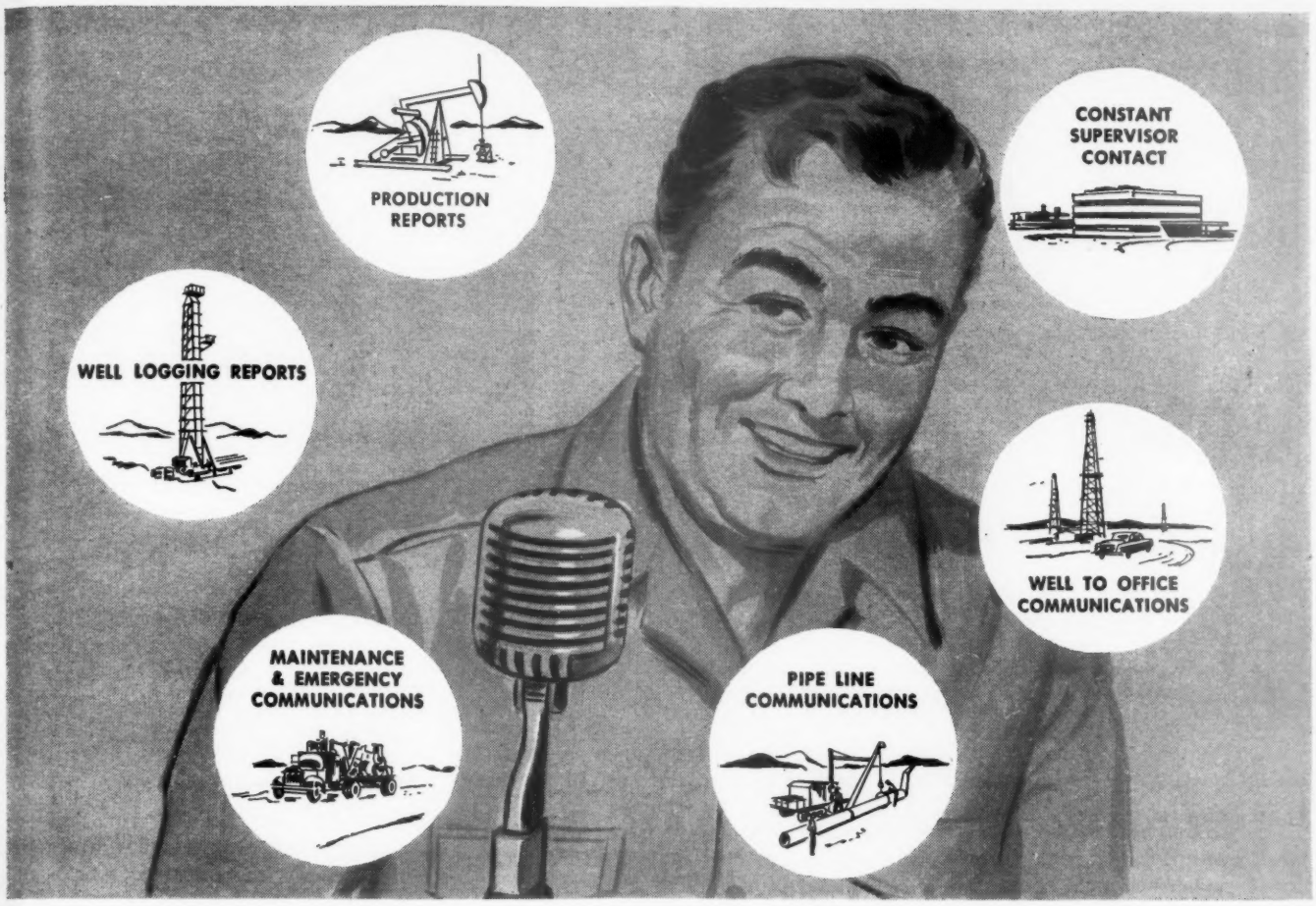
Plantation Pipe Line Company has in operation five remotely controlled, unattended, electrically powered pumping stations. We do not mean to imply that these stations have been unsatisfactory; on the contrary, we are well pleased with the results obtained and expect to build more of them in the near future. It is our thought that the industry may be interested in what operating experience has indicated to us to be desirable design features for such stations, equipment which needs improving, and necessary maintenance procedures.

Design for Maximum Safety

An unattended station must "think for itself" and must try to protect not only itself but its neighbors from the hazards it may introduce. Good design can make the protection job much easier.

For example, an outdoor pump station is practically defenseless against wind-blown sparks from a forest or grass fire. It is highly desirable to house the pump and all small valves, piping, and other equipment that might leak products in a good substantial building with a concrete floor, drained to an underground sump tank. This building should have an exhaust fan, and air should be drawn in through nonflammable filters. A further precaution against exterior fires, which seems worthwhile, is a strip of concrete pavement extending at least 25 ft around the building, with trees and brush cleared out for 150 ft or more away from the building.

Confining all leaks inside a building, where they can be drained to a sump tank, also provides another protection. A float switch on the sump tank operating on high level can shut down the station and close station valves, thus



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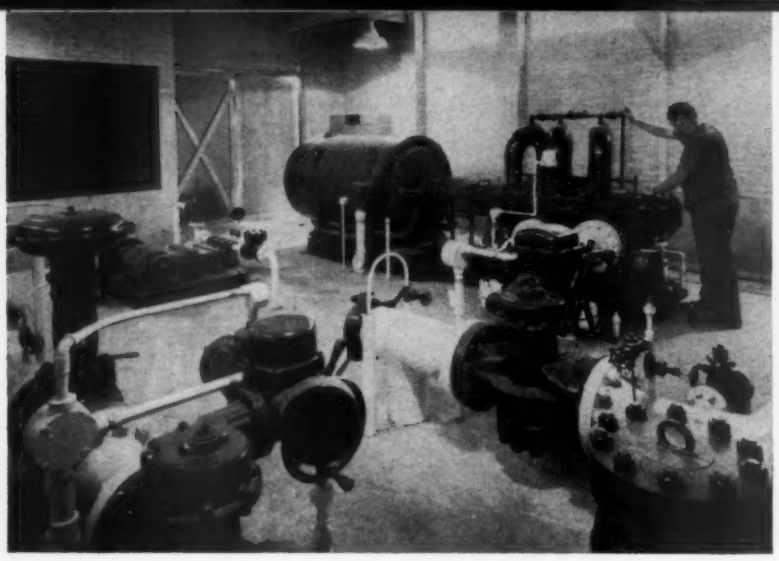

FIG. 2. Interior view of Smith Station pump building, taken during construction

FIG. 3. Microwave equipment at Bremen Station

preventing product from spreading over the countryside in the event of a bad leak.

All equipment and wiring in the pump building should, of course, be designed for class No. 1, group "D" service. Whether the main motor should be explosion-proof or enclosed force-ventilated may be debatable, but it is certainly true that the explosion-proof motor does not require any additional gadgets—which could fail—to make it safe, as does the force-ventilated type.

Because it is not practical to make the station control equipment and switchgear explosion-proof, explosive vapors must be kept away from it. If the control gear is placed in a room adjoining the pump room, additional equipment is required to maintain a pressure differential between the two rooms and to check for explosive mixtures in the control room. At little or no additional expense the control gear can be located a safe distance away from the pump area, either out of doors or in a separate control building. Our preference is for a separate control building, 50 to 150 ft away from the pump building, depending upon relative elevations. Troubles always seem to develop on cold rainy nights, and it is a bit difficult for an electrician to concentrate on a complicated wiring diagram and hunt for trouble when he is wet and cold.

Recommended Layout

Fig. 1 shows the general layout of one of the single-unit stations which is remotely controlled over a microwave link from an attended station approximately 50 miles upstream. Two such stations are located on an 8-in. branch line from Bremen, Georgia, to Knoxville, Tennessee, and both have been in operation approximately two years. The small building in the foreground houses the radio equipment, channel multiplexing equipment, and a 6-kw standby diesel generator. In the larger building on the right are the main pump (800 hp), 5-hp sump pump, and all station valves, piping, and the like, as shown in Fig. 2. The control and switchgear equipment is located in the building to the left. In the background can be seen the incoming and outgoing station block valves, near which are located the electrical pickups to detect passage of scrapers.

Equipment in these stations has, in general, been satisfactory. However, there are some changes, as will be discussed later, which we feel would be desirable. The arrangement of buildings and the layout of equipment we still feel is safe and about as good as any other unattended stations we have seen.

Equipment Test

In our opinion no equipment is too good for such an application. An unattended station is certainly no place to economize by using "dime-store" gadgets. Even after purchasing the best equipment available, a lot of grief can be avoided by testing it—not just a simple final sequence test, but a thorough check and test of each individual component. Loose nuts and defective parts show up even on new Cadillacs today.

Of course, all reputable equipment is guaranteed, but it would be small comfort, after blowing up a $250,000 station because of failure of a $25 relay, to find that the manufacturer will gladly replace the relay, provided you send him the old one back freight prepaid and install the new one yourself. The manufacturers of the mechanical equipment are not blameless either. One of our pumps, specified to be tested at 2000 lb and bearing a name plate stating that it had been tested to 1500 lb, leaked through a sandhole in the case at 500-lb pressure.

We have not actually blown up a station, nor even set fire to one, but we have had some things happen which, with other types of station design or under different circumstances, could have resulted in serious damage.

Recommended Equipment Changes

Lubricated plug valves were used in the stations for motorized station and pump valves. Inasmuch as most of these stations are on lateral lines and make frequent starts and stops, a utility man has to make two to four trips a week to the unattended stations to lubricate the valves. Unless some satisfactory means of automatic lubrication can be devised for the plug valve, a nonlubricated type of valve would seem preferable.

On the first four stations, the pressure controllers used have hydraulic-pressure sensing elements. At the last station built, electrical strain-gage pressure-sensing elements were used to power the pneumatic controller. The electrical system is more accurate and requires less maintenance. Further it eliminates small product piping that is always a source of leaks and other troubles. As for the pneumatic controller and air-operated throttle valve, we are not too happy with these, and hope someone someday will devise an ell-electric controller and throttle valve. In spite of elaborate precautions such as compressor aftercoolers, moisture traps, filters, and the like, we are still plagued with frozen air lines to the throttle valve in the winter.

As mentioned before, small product lines are a constant maintenance problem. They leak and they plug up with scale. Some of the station emergency-shutdown devices, such as high and low pump suction pressure, and high outbound-line pressure, are dependent for operation on the small product

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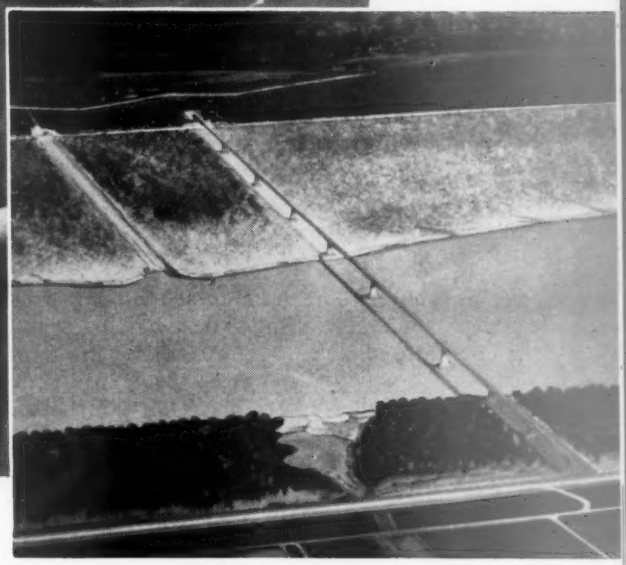

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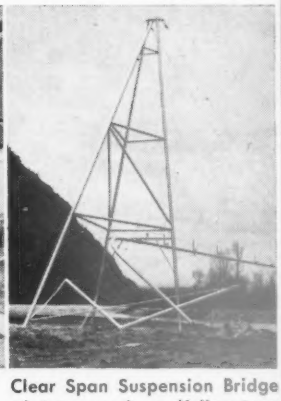
Girder type construction employed on International Bridge at Weslaco, Texas.



Clear Span Suspension Bridge of type used on Yellowstone Pipe Line in Montana and Wyoming.

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Bridge illustrated designed for three 30″ pipe lines. *Carrying capacity for each additional line may be added for only 10% of original cost.* Lines may be repaired, replaced or removed without taking bridge out of service. Steel used is four times as resistant to corrosion as normal structural steel. Girder width on top 8′. Maximum depth 16′. Minimum depth 8′. Designed to absorb 130 mile per hour wind load. Time required for construction is less than 5 months.

Has this type of Construction been used before?

Yes — most successfully. Clear Span Engineering Company designed the 7 Clear Span Bridges erected on Yellowstone Pipe Line Company's 10″ line in Montana and Wyoming, as well as the box type girder construction used on the International Bridge at Weslaco, Texas, and on heavy oil field bridges.

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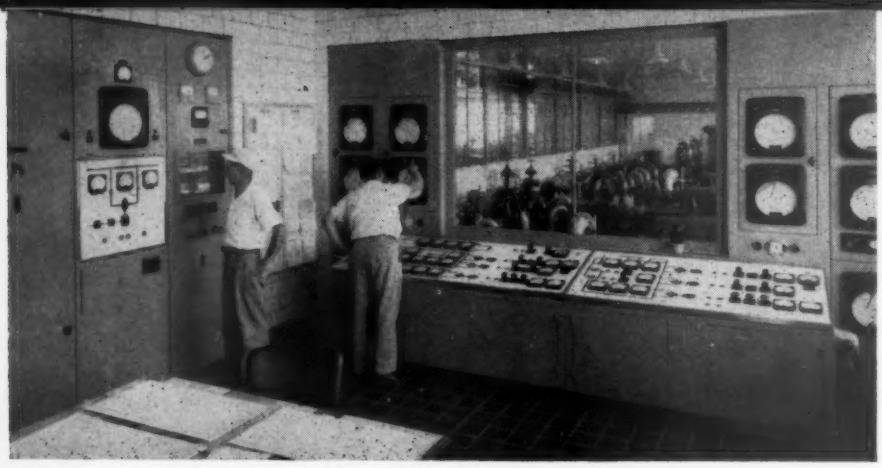

▲ FIG. 4. Interior of station control room at Bremen. Unattended stations are remotely controlled from this point

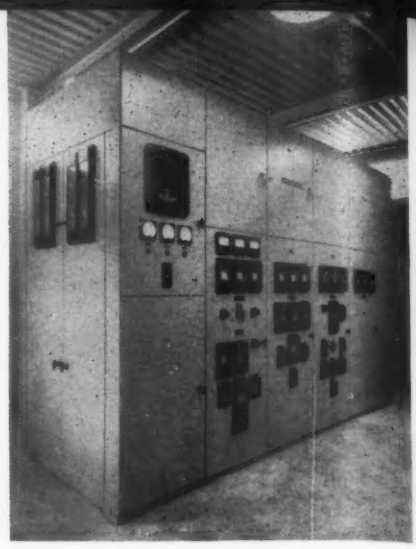

FIG. 5. Metal enclosed, dead-front construction is used in switchgear at remote stations ▶

lines. This is a weak link in the protective system, and we are trying to devise something more reliable.

Some of the scale that plugs up the small product piping could be kept out by adequate filters. We feel that these would only create an additional maintenance problem, however, and we use only simple strainers to protect the main pumps. We have had difficulties with wire bristles lost from scrapers. Occasionally one of these will go through the strainer and pump and will lodge in the station throttle valve, causing the valve to stick. We are experimenting with a magnetic device to install in the strainer to catch the stray scraper bristles.

To prevent surging of the line and overloading of the motor during the line-packing period, we installed flow controllers at the first four stations. These use differential-pressure electrical strain-gage sensing elements across orifice plates, and the small piping to the differential-pressure cells has been a source of leaks. Furthermore, this system complicates the main-station piping because of the necessity of installing straightening vanes and straight runs of pipe above and below the orifice plate.

On our most recent station, a load controller, operating on main motor loading, was substituted for the flow controller. Where it is not necessary to telemeter flow back to the control point, we feel that the load controller is preferable to the flow controller. The load controller costs less, requires less maintenance, and has the further advantage that it will permit more flow on light products.

Supervisory Telemetering

Two small stations, each with one 300-hp main pump, operate without supervisory control. These are on 4-in. branch pipe lines. Remote start and some sort of simplified supervisory stop is accomplished by dialing over the teletype circuit, and no intelligence of any kind is brought back to the control point. However, the control point in both cases is the originating point for the line so that the operator, by watching his pressure and flow, can tell when the remote station is operating. Even for such small and relatively unimportant stations, we now feel that control and telemetering of at least station suction and outbound-line pressures is desirable.

On two single-unit 800-hp stations on an 8-in. lateral line, we went overboard on supervisory control and telemetering, and wound up with this equipment costing us $38,000 per station. Experience has shown that some of the intelligence brought back to the control point from these stations is not necessary and that, by grouping some of the fault indications on the same supervisory point, the cost of adequate supervisory control and telemetering for a single-unit can be brought down to less than half of the foregoing figure.

Transmission of Supervisory Intelligence

The problem of whether to purchase microwave radio or to lease telephone circuits for transmission of intelligence for remote control of an unattended pumping station is not, in our opinion, susceptible to a general solution applicable to all pipe lines. We have both microwave and leased-wire control and find that both give better than 95 per cent reliability. At the present time we feel that, for our system, the leased wire is the most practical and the most economical. However, where there is a legitimate use for the additional channels that can be added at very little expense on the radio, there would undoubtedly be applications in which the microwave would be preferable.

Fig. 3 shows a view of the 2000-mc microwave equipment—with doors removed—installed at Bremen station, the originating point for the 152-mile radio system operated by Plantation Pipe Line Company.

The center unit in the front row is the main RF, that on the left the standby RF, and the unit on the right contains the channel multiplexing equipment. The cabinet in the rear contains control for the standby diesel generating unit (located in another room), tower lights, building lights, radio-fault annunciator panel, and radio remote-control panel from which the standby generators at all remote radio stations can be test started and the radio itself can be switched from standby RF to main RF at any of the remote stations.

In Fig. 4, which shows a portion of the control room of our Bremen station, which is manned, the second wall panel on the left shows the station diagram, control buttons, and indicating lights, and the pressure gages and flowmeter for any unattended station located approximately 50 miles away. The small black panel, barely visible below the white station-diagram panel, is a duplicate radio fault-indication annunciator to the one in the radio building (Fig. 2). Although this serves to advise the operator of any radio faults, its main purpose is to advise of tower-light outages at all radio stations, as these must be reported as soon as possible to the Civil Aeronautics Authority.

Maintenance Procedure—Radio

Inasmuch as we have only 152 miles of microwave radio, with seven radio stations (of which three are repeaters), we do not have a radio department. We have one combination electrician and radio technician, with a helper, who takes care of normal maintenance on the radio and also the electrical maintenance of two unattended and one attended pumping stations along the route of the radio.

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The Authors

T. V. Bockman

R. S. Cannon

T. V. Bockman has been electrical foreman for Plantation Pipe Line Company, Atlanta, Georgia, since 1948. He is responsible for all maintenance and construction work for 11 pumping stations, four delivery terminals, and a 156-mile microwave system. He joined Plantation in 1946 as an electrician.

A graduate of Georgia Institute of Technology, he was employed by Bell Aircraft Corporation following graduation.

R. S. Cannon was with Creole Petroleum Corporation, Caracas, for 20 years. A graduate of the University of Illinois, he attended a Westinghouse graduate student course and later worked in the electrical drafting and design department of the Pennsylvania Railroad. For two years he was in the distribution department of the Mexican Light and Power Company, Mexico City, Mexico.

Radio-tower maintenance, including lamp changing, is contracted. Our two men have a panel truck assigned to them to carry their tools and the usual instruments necessary for radio and electrical maintenance. In addition to the three stations, these men look after the radio equipment at three repeater stations located along the 152-mile route.

These men also maintain two sets of carrier equipment used to control an unattended booster station on the main line 26 miles from headquarters. This audio carrier is used to multiplex a leased wire, voice grade circuit over which the station is controlled. It includes two channels for supervisory control (with automatic transfer), four telemetering channels, and two channels for emergency start or stop (in case of failure of supervisory control). The carrier equipment was placed in service in September, 1954, and to date has required no maintenance.

Headquarters for these two men is at our division office at Bremen, Georgia. It was found most desirable to locate them there rather than at some point in the middle of their work area. Bremen is the critical point for radio control, inasmuch as the radio frequency at Bremen determines the operating frequency for all the other radio stations in the division. Then, too, the supervisor responsible for maintenance work can exercise better control of working conditions, and he is in a better position to pass on information from higher echelons of management.

Our radio system has been in operation since September, 1953. During the first four months of operation the manufacturer of the equipment furnished us a technician for trouble shooting and to train our maintenance personnel. Since that time our maintenance men have been entirely on their own, and our system has not been out for longer than two hours up to now.

Having complete standby RF equipment at each location has been of great help; otherwise, our system would have been useless at least 25 per cent of the time.

We feel that our men, however, with no previous electronic background at all, have done an outstanding job in keeping up our equipment. The fact that we have two different means of voice communication between all locations has been a help in maintaining our system. One of the voice-communication devices is a clearchannel voice telephone that is connected between our division office and all the pumping stations; the other is a service telephone that is connected between all the radio buildings of the system. This service telephone operates over the radio alarm and control channel.

In addition to the radio equipment, these men service the batteries for the auxiliary power plants in the radio buildings and the batteries for the switchgear, make adjustments to pressure and flow controllers and protective pressure switches, and assist in switchgear repair work. Their radio work includes checking the output and frequency of each station, changing out filters in the cooling-air system, and keeping the equipment clean and in good operating condition.

We have had the usual number of tube failures, blown fuses, burnt-out resistors and capacitors, and open circuits in relay coils. Tube life has not come up to expectations; in the past year we have replaced $1600 worth of tubes of one kind alone. A few troubles have cropped up which were a little out of the ordinary. At one of our tower coaxial cables we found a hole about the size of a .32-caliber bullet in the shield, and the area around the lower lights was peppered with buckshot. Evidently one of the natives objected to the red lights so close to his home. At another location our signal was interfering with a VHF radio system located on an adjacent forestry tower. Moisture in the coaxial cables on the towers has caused us a great deal of trouble and the tower maintenance crew a lot of work in changing out gaskets at coaxial-cable joints.

Radio operation in general, however, has been good, and we attribute a large part of this to the excellent maintenance our crew has been giving the equipment. We feel our system is an easy one to learn and is one which can be worked on with a minimum of trouble.

Maintenance Procedure—Mechanical

The division mechanical crew, consisting of a foreman and three mechanics, takes care of the mechanical maintenance at our remotely controlled stations in addition to the other stations in the division. This group is responsible for the repair of pumps, air compressors, water pumps, and valves, and for the mechanical repair of the 800-hp pumping motors. Their repair work on the 800-hp motors includes replacement and fitting of bearings as necessary, checking alignment and spacing, and replacement of worn oil rings. This group travels in a truck with a special panel-type body capable of carrying a complete rotating element for the large pumps and all other repair parts necessary for their work.

In addition to the foregoing items, the mechanical group services the seven diesel engines used to drive the 6-kw emergency power generators in our radio buildings. On the original installation we did not have purchased power at two of our repeater stations, and two diesel engines were installed, one running continuously with automatic transfer to the standby unit in case of failure of the normal engine or generator.

This installation proved troublesome, as the engines used a large quantity of oil and several of the generators failed. We have since installed a new type of generator at all locations and have obtained purchased power at all locations. This has greatly reduced the maintenance costs at these locations, as we do not have to make a trip to these locations every 10 days to check the diesel-fuel storage tanks, diesel engines, and generators.

Our mechanical maintenance record has been very good. It has been necessary to replace one 800-hp motor at one of the stations because of an explosion seal working loose and throwing a whip in the rotor shaft. This we feel was a manufacturing error and not the result of poor maintenance.

We have had the usual pump mechanical-seal trouble caused by welding beads, scale, and dirt from new sections of pipe line adjacent to the

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stations. This could be foreseen from our experience on other stations on a new line. Some difficulty was experienced with hydraulic nonslam check valves, between the suction and discharge of the pump, failing to close after a scraper run when the pump was restarted. After eliminating the nonslam and hydraulic features of this check valve, we have had no further trouble. We have had no other unusual mechanical problems.

It is necessary for the mechanical and electrical departments to work together very closely on maintenance at a remotely controlled station. One department can often make repairs to the other department's equipment without calling out their men to make a special trip to the location. This has proved advantageous in the past because, even if one department cannot repair the faulty equipment, the knowledge gained by talking to someone who has a good knowledge of how the equipment should operate helps the department repsonsible to bring the correct equipment to repair the trouble.

Inasmuch as the supervisory control diagram at our attended pumping stations is arranged to distinguish between electrical and mechanical troubles in the equipment at the remotely controlled stations, the job of maintenance is greatly simplified. The trouble lights give us a good indication of what is wrong with the equipment before our crews leave for the stations. We can then take with us the necessary repair parts and can do the repair work on arrival with no extra trips necessary to pick up repair parts.

Maintenance Procedure—Electrical

Our electrical crew consists of three well-qualified electricians. These men perform all the major repair and maintenance work on our four remotely controlled stations, as well as all other electrical work in our division, consisting of six other pumping stations, four terminals, and the division office. These electricians check the oil circuit breakers, pumping motors, auxiliary motors, and other equipment at definite intervals.

As an aid to better maintenance, we have found that keeping a set of equipment cards at the remote station and a duplicate set at our division point helps us in scheduling necessary repair and maintenance work without interfering with normal pumping operations. On these cards is a complete history of each piece of equipment, showing the services performed and its general condition. By taking advantage of seasonal ups and downs in throughput demands, we can schedule major main-

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Two-wire line links 10 stations and Houston dispatcher's office in low-cost Automatic Telemetering System for Gulf Interstate's 845-mile gas pipeline.

Actual recording on standard teletypewriter paper; 8 of possible 12 channels used. Can also transmit flow, temperature or shaft position.

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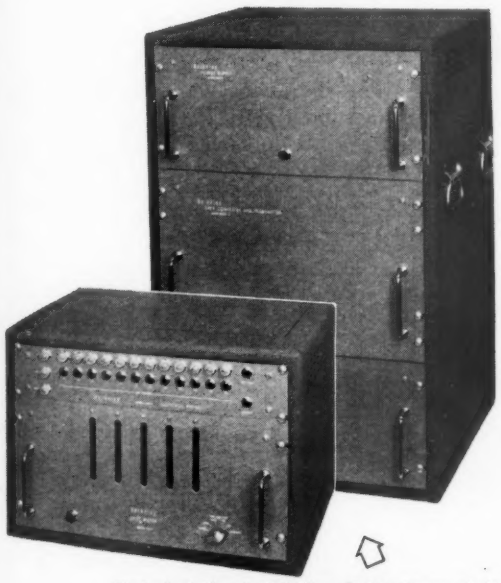
010	1	740	645	3	735	04	380	06	781	
	01	345	375	03	364					
	2									
	02									



Typical station installation. Meter (lower photo) also provides digital reading of data from any 12 transducers in the station without transmission; may be set for automatic test scanning.

problem: How to link together 5 compressor stations, 5 gathering and distribution stations and the Houston dispatcher's office in a low cost system for telemetering pumping station data over distances of 1,000 miles.

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features include:

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tenance at times of less demand for use of the stations.

Our equipment at these remote stations is as nearly foolproof as we can make it. All switchgear is completely metal enclosed and of dead-front construction, as shown in Fig. 5. All motors in hazardous locations are explosion-proof and are of squirrel-cage induction design for safety and ease of maintenance. We do not allow maintenance work to be done at these locations unless there are two men present. This eliminates the possibility of a man becoming sick or injured and not having any way to let us know his condition so we can get help to him. In our two years of operation of these stations we have never had an accident or injury.

For transportation these three electricians use a pickup truck with all necessary tools, instruments, and some repair parts carried at all times. We do not carry repair parts for every trouble possible because, as we have mentioned before, the supervisory control board gives a good indication of what trouble is present. We can then pick up repair parts at our division warehouse before leaving for the job.

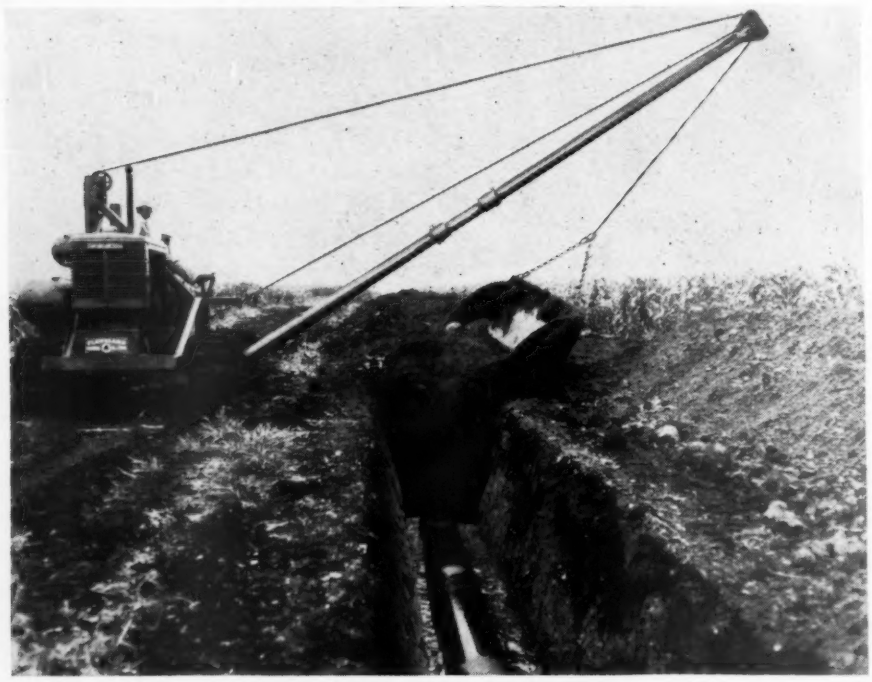
Either our electrical crew or our radio crew can perform minor maintenance work or trouble shooting on the electrical equipment. Whichever crew is closer to the job is sent to clear up troubles and get the pumping units back on the line. We feel that by not allowing our radio crew to specialize in radio work, we can get more useful service from them, and they will become more familiar with operations as a whole.

Electrical troubles have been of a minor nature in all of our remotely controlled stations. None of the troubles experienced have caused a shutdown of the station for more than a few hours. Included in our minor troubles have been frozen air lines to pneumatic pressure controllers, stopped-up tubing lines to protective pressure switches, failure of timing relays in our sequence-control setup, blown fuses in our battery and flow controller circuits, and burnt-out coils on breaker operating mechanisms. We believe that the time spent in selection of the electrical equipment for these stations, as well as an intensive training program for our electrical maintenance men, has paid big dividends when it comes to locating and repairing electrical troubles.

Acknowledgment

This discussion was presented at the 6th Annual API Products Pipe Line Conference in Chicago, Illinois, May, 1955.

* * *



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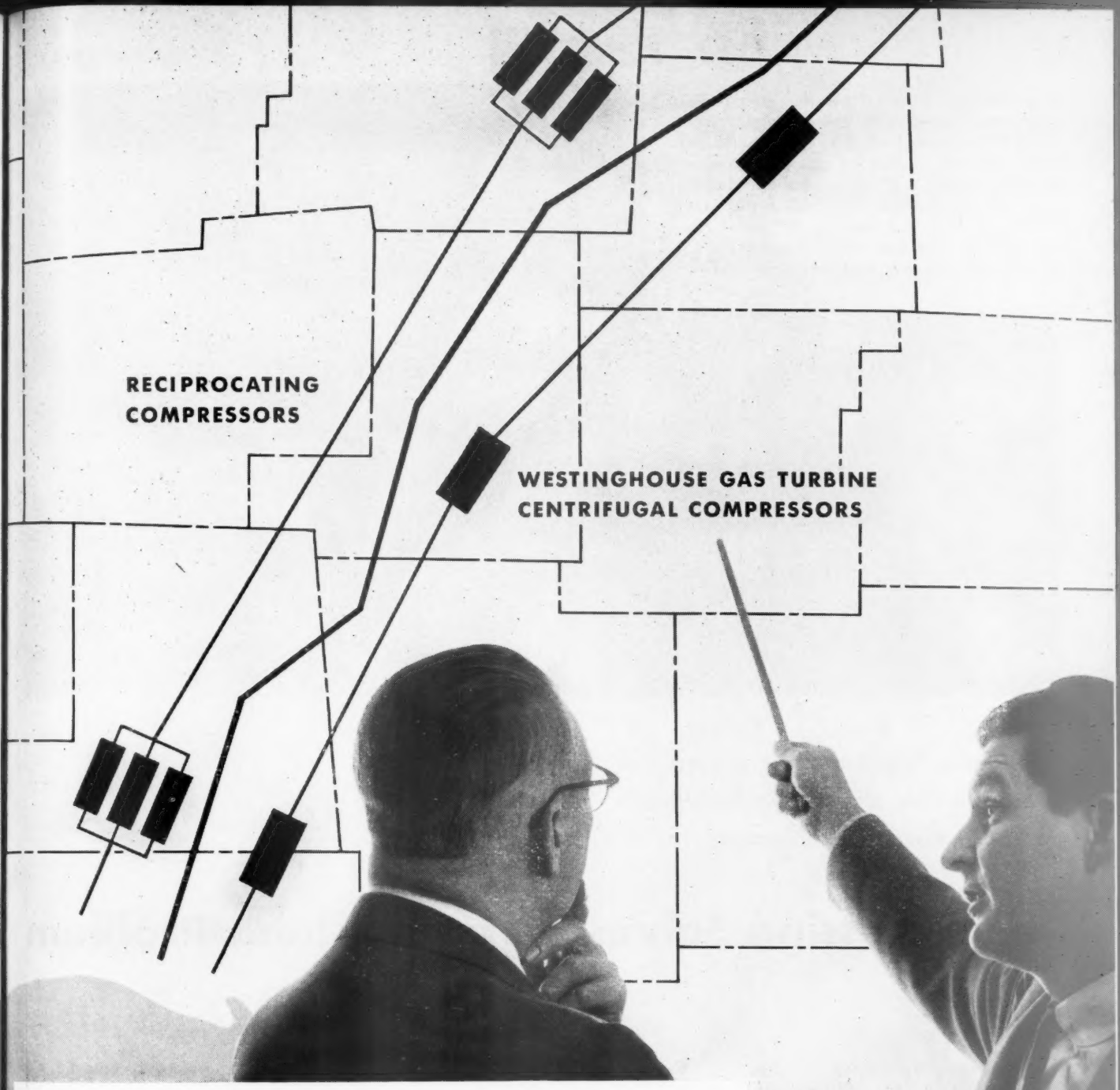

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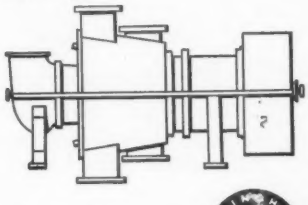

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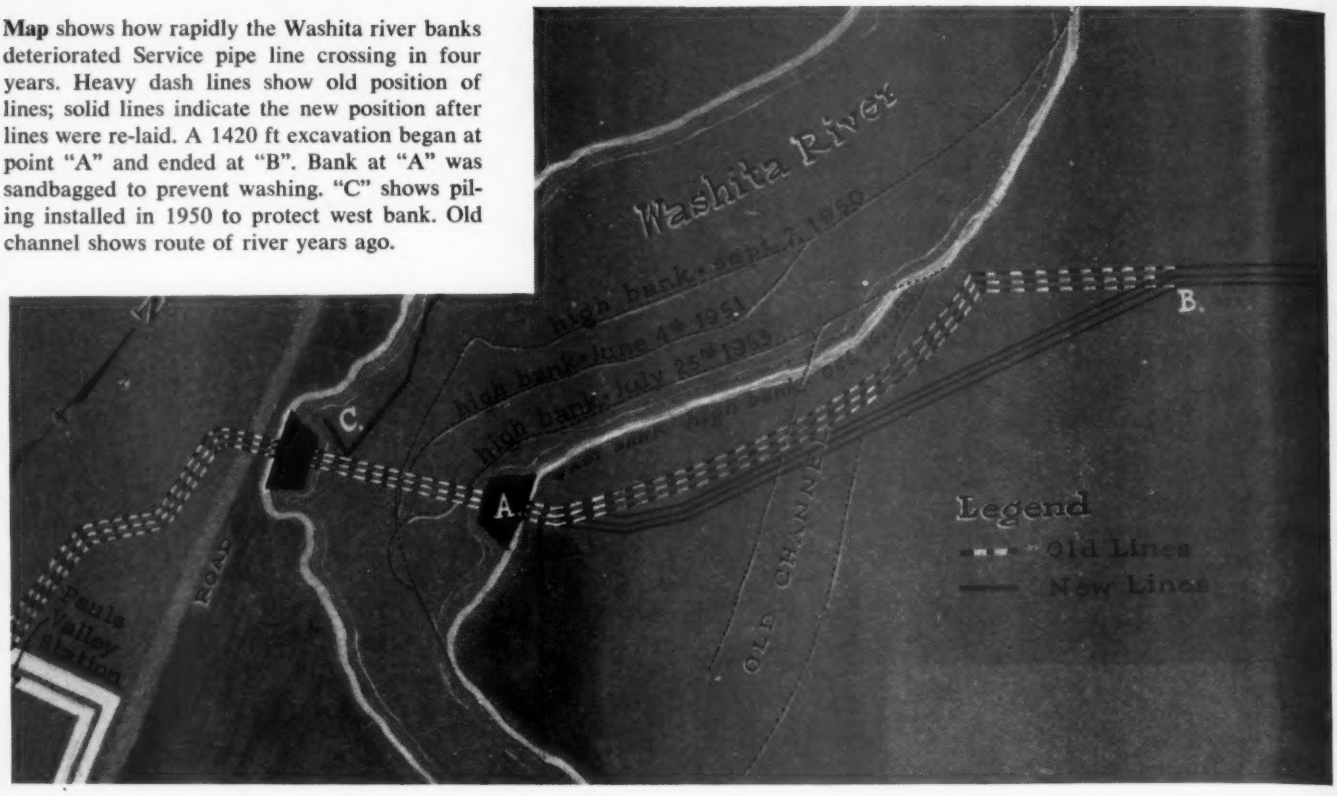


Map shows how rapidly the Washita river banks deteriorated Service pipe line crossing in four years. Heavy dash lines show old position of lines; solid lines indicate the new position after lines were re-laid. A 1420 ft excavation began at point "A" and ended at "B". Bank at "A" was sandbagged to prevent washing. "C" shows piling installed in 1950 to protect west bank. Old channel shows route of river years ago.

Rampaging Washita River played havoc with lines of Service Pipe Line during flash floods; 100,000 cu yd earth moved by contractor, all lines relaid as

Deep Crossing Solves River Washout Problem

CARL I. HUSS*

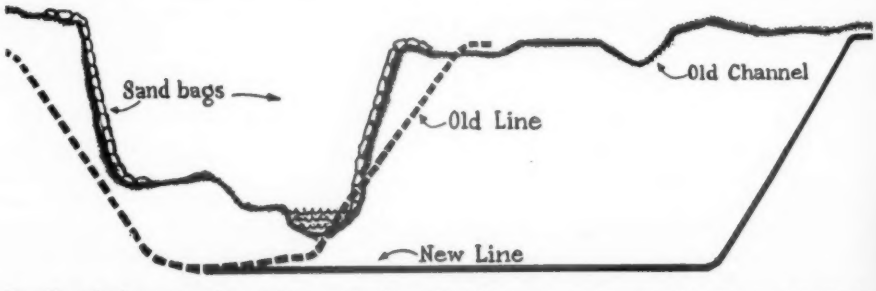
A summer flash flood on the Washita river in 1953 ripped the soil from Service Pipe Line Company's three lines and left them dangling dangerously. It was the second time in three years that the usually sluggish stream caused the company trouble and expense at its river crossing near Pauls Valley, Oklahoma.

As recently as World War I, the Washita was a stream with well-defined banks and the general appearance of a well-constructed irrigation ditch. Its banks were stabilized by a heavy growth of willows and large cottonwoods and native elms. But now most of the land along its banks has been cleared so that heavy spring rains bring quick run-offs and flash floods. Flood water rise and recede rapidly eating large chunks out of the high banks.

Service's three lines, two 8-in. and one 12-in., cross the river several hundred yards from the Pauls Valley pump station. There the river makes two sharp reverse bends that roughly form an "S." Service's lines cross the river just above the second bend (see map).

In the spring of 1950, the Washita river went out of its banks and flooded the Pauls Valley pump station grounds. Service crews sand-bagged the doors so that little water got inside; the flood, however, left the lines exposed at the river crossing.

Service personnel lowered the three lines deeper into the banks and under the channel. The west bank, the nearest



Profile of river crossing. Lines cross the Washita east and west. Old channel indicates where river once flowed. Lines were lowered far below this old channel in case the river ever reverts backs to it.

*Service Pipe Line Company, Tulsa Oklahoma.

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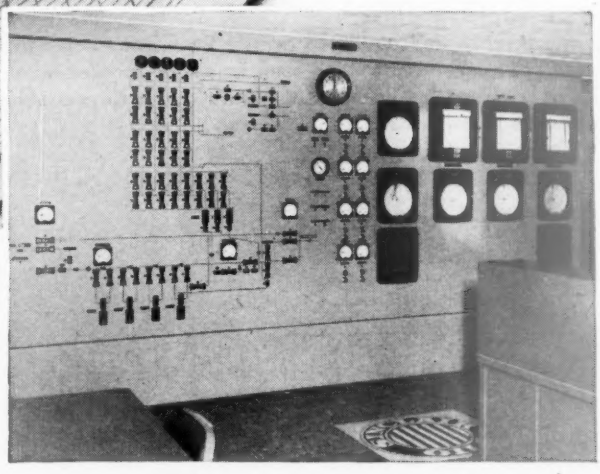
The M-40 Auto-Selector has two measuring elements and control mechanisms — also a combined air relay. It actually does the work of two instruments . . . with one or the other variable under control at all times. The transfer of control from one variable to the other is smooth, instantaneous, and with no upset. Any type of control action may be used. Any combination of related variables may be controlled-pressure and flow; temperature and level; two flows; two pressures; etc.



SINCLAIR PIPE LINE COMPANY'S new 670 mile, 22-24 inch line from Cushing, Okla., to East Chicago is operated by all-Foxboro control instrumentation, based on the unique Auto-Selector Controller. Above: part of control panel at Cushing Station.

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Extent of the cut may be seen by looking across the river to the east. Pipe foreground is discharge on suction dredge out of picture to left. It lowered lines beneath the channel.

A view of completed job. Seen across the river to the east are the sandbags where the lines were re-laid. Sandbags are indicated by "A" on map (first page of article.) In the foreground may be seen the cut made by the dredge in lowering the lines under the channel proper.

the station, is straight up and down at that point and highly susceptible to washing.

To stabilize the bank, the crews made piling out of 40-ft sections of junk pipe and drove them 18 ft into the river bed along the west bank. They then welded wire mesh to the piles. This prevented swift water from sloshing against the sandy bank and causing it to cave in.

They also placed about 5000 bags filled with one part cement and seven parts soil over the spot where the lines were buried. The east bank slopes gradually and natives thereabouts told company employees it would not cave in, or, at least it hadn't for years.

The latest flash flood made the natives eat their words. The flood ripped big chunks from the east bank and left Service's lines swaying above the swift water. The west bank, bolstered by the piling, held.

As an emergency measure, the Pauls Valley connection crew took the lines out of service, cut them and moved them back out of harm's way. That was only a temporary move until a contractor with heavy equipment could be engaged to lower the three lines.

Pentizien, Inc., of Omaha, Nebraska, won the contract to lower the lines. Three Service employees were assigned to the job: Leslie Beavers, welder-pipeliner at Pauls Valley, served as company inspector; Kenneth King, engineer at Shawnee, shot elevations and did other engineering work required at the site, and Walter Busey, crew clerk at Pauls Valley, kept time and material records.

The Pentzien crew, headed by Forrest Andrews, field superintendent, worked the job in two shifts of 10

Flash flood in July, 1953, left Service Pipe Line's two 8-in. and 12-in. lines swinging as shown. As soon as waters receded some, company crews relocated the lines out of harm's way until contractor could be called in to lower them.

Kenneth King, Service Pipe Line engineer, who assisted with the project stands near the west bank of the Washita directly over Service's lines. Pipe and wire mesh (foreground and background) were installed three years earlier when lines washed out. During last flood this west bank was not damaged. Lines washed out on the opposite bank where no piling had been installed.

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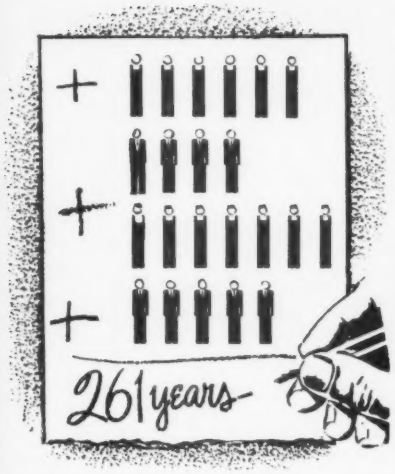

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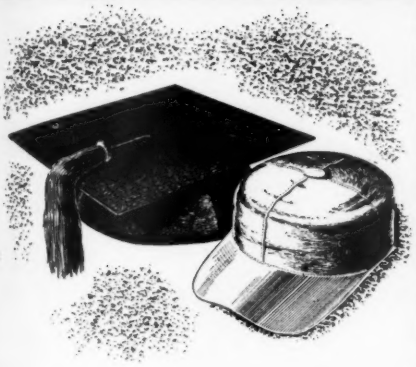
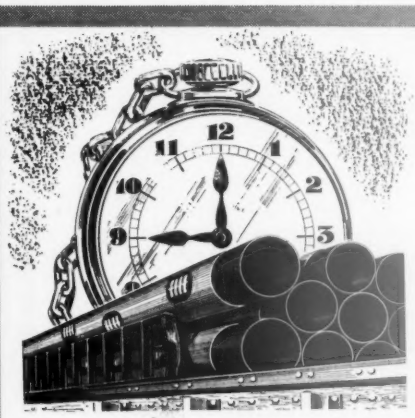


TWO-WAY ABILITIES

PIONEER'S KNOW-HOW



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IN EVERY INDUSTRY there's a leader with certain intangibles that tip the balance between superior and mediocre results. In the pipe-protection industry that leader is Hill, Hubbell & Company—and the intangible "things that money can't buy" add up to a superior type of service which can come only from longer experience and technical knowledge. This pioneer's know-how . . . *in addition* to the most modern processes and equipment . . . keeps Hill, Hubbell well out in front.

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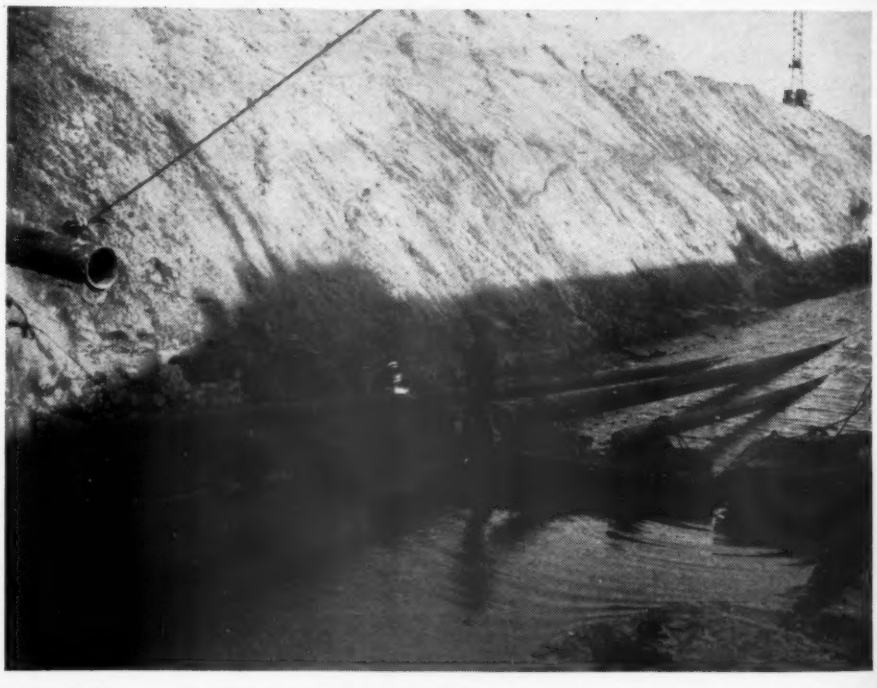

Top, looking north along the 1420-ft cut that was made by removing around 100,000 cu yd of dirt. Notice draglines and bulldozers in the background backfilling the trench. As men moved along the ditch laying pipe, the backfilling crew followed behind them.

Center, closeup shows line swung into place. Old lines were replaced by new pipe, some 1350 ft on each one during operation. Pentzien, Inc., of Omaha, Nebraska, had contract.

Bottom, welder makes the first tie-in on the 8-in. Center line is a 12-in. and third line, other 8-in. Pumping continued through old 12-in. until new lines could be put into service.

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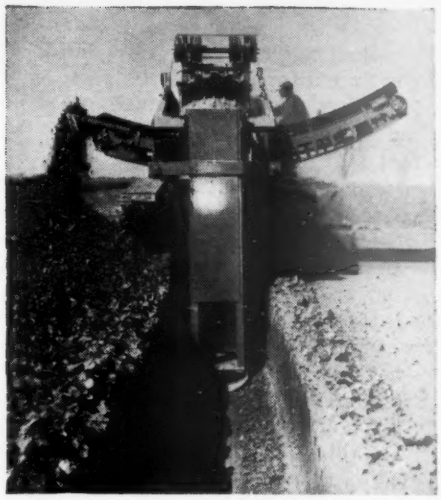

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hours each. Their major task was digging the trench for lowering the lines. Two draglines, working through the day and through most of the night by searchlight, finished excavating the canyon-like trench within a month.

The completed trench measured 1420 ft in length, 30 to 34 ft deep and 40 ft wide at the bottom. It extended east from the river bank about 500 ft, then dog-legged north another 900 ft. About 300 ft from the north end, it sloped to the surface at ratio of 1 to 10.

King estimated Pentzien excavated nearly 100,000 cu yd of dirt, enough to cover a football field to a depth of around 20 yd.

Meanwhile, the crews raised the three lines from the channel proper, reconditioned them and let them settle back to the bottom. Later, they dredged the lines deeper into the river bed.

Starting at the east bank of the Washita, the crew replaced some 1350 ft of pipe on each line with new pipe from warehouse stock. Since Service had to maintain pumpings through the system, they did not replace all 3 lines at once. Here's what they did:

Pumpings continued through the 12-in. while they took up the two 8-in. line. By the time they completed this take-up and reconditioned the lines under the river, the draglines had finished the trench.

The crew started laying the three new lines along the trench bottom, beginning at the end farthest from the river. They tied in the 8-in. lines at that spot, and left the end of the 12-in. exposed for later tie-in. As the men progressed down the trench toward the river, the draglines and bulldozers behind them started the tremendous task of backfilling the 100,000 cu yd of dirt.

When the crew finished laying the three new lines the length of the trench, had reached the east bank of the river. There they connected the new and the reconditioned 8-in. lines together.

The 8-in. lines were tested and put into service. This enabled the crew to take the 12-in. out of service for the tie-in. All three lines were then put in service.

Backfilling the trench continued while the crew took up about 1320 ft of the old 12-in. Pentzien wound up the project by sandbagging the backfill on the east bank.

Some day the Washita may revert to an old channel long since filled in (see map), thus straightening out the lower bend in the "S" curve. That is why the trench was dug so deep and so far back from the present channel. Should the river revert to the old channel, the newly-built lines will be several feet below the new river bed. *

Toronto-Montreal Gas Line May Be Laid This Year

Likely to make a start and perhaps be completed this year is the proposed natural gas pipe line from Toronto, Ontario, to Montreal, Quebec, which represents an attempt by Trans-Canada Pipe Lines Limited to salvage something in immediate business from its ambitious project for an all-Canada pipeline between Alberta fields and eastern Canada.

The new proposed line, for which Trans-Canada is making formal application to the Board of Transport Commisioners for a construction permit, would be about 400 miles long, following much the same route as the Trans-Northern products line.

The company estimates that is has spent nearly $7,000,000 on engineering surveys and preliminary design work on composite project.

Under the extensions granted by the Board, arrangements for financing the construction of the project must be completed by October 31, 1955; construction of the 2250 mile pipe line is to begin no later than June 30, 1956; and removal of natural gas from the province shall be on or before December 31, 1956.

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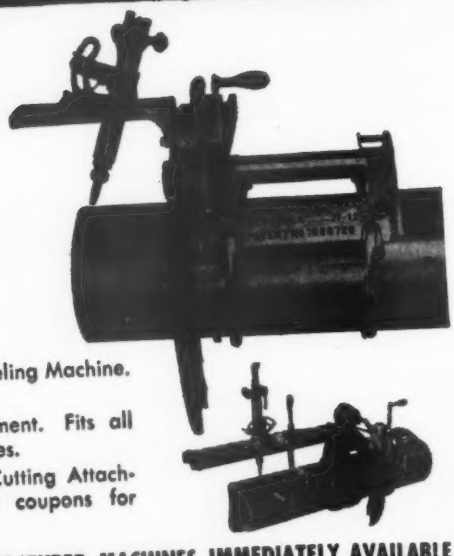

Illustrated above: Mathey Pipe Cutting and Beveling Machine. Cuts pipe at any predetermined angle.

Illustrated left: Mathey Out-of-Round Attachment. Fits all sizes of Mathey (and Mathey-made) Machines.

Illustrated right: Mathey Shape and Coupon Cutting Attachment. For cutting pipe intersections and coupons for welding analysis.

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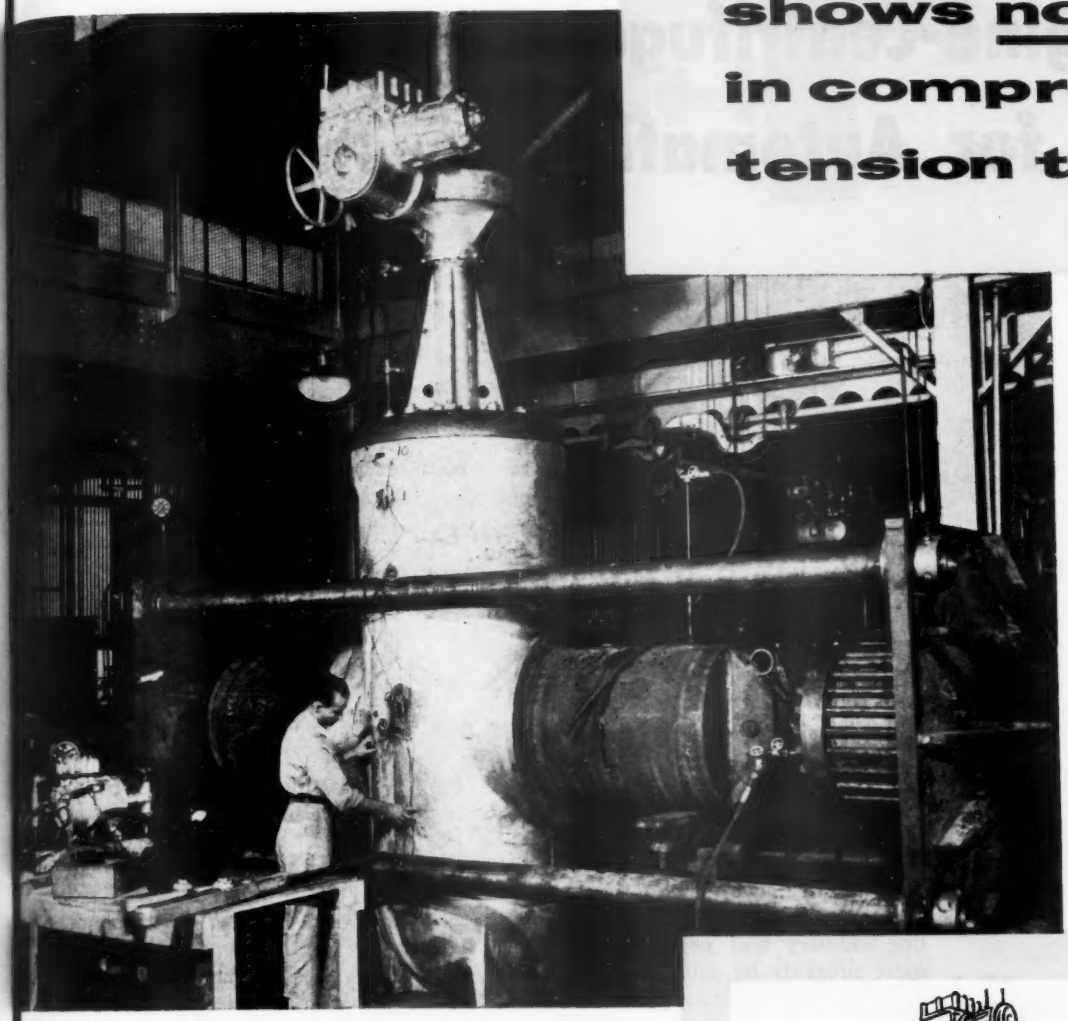
W-K-M Valve shows no leak in compression-tension tests



A special test was made in the W-K-M plant to determine what effect external compression and tension loads would have on seal-off and operation of a W-K-M Valve.

This test was conducted using a 30" ASA 400 p.s.i. weld-end gate valve operated by an electric motor. Ten strain gages were placed in the valve at locations shown on the diagram at right.

Using a hydraulic cylinder, an external differential tension load of 675 tons was applied to the valve while maintaining maximum working pressure against the gate.

During the tests the recorded strain-gage readings indicated no fibre stresses in excess of code allowables, indicating no appreciable body distortion. The valve did not leak and operated freely under all conditions.

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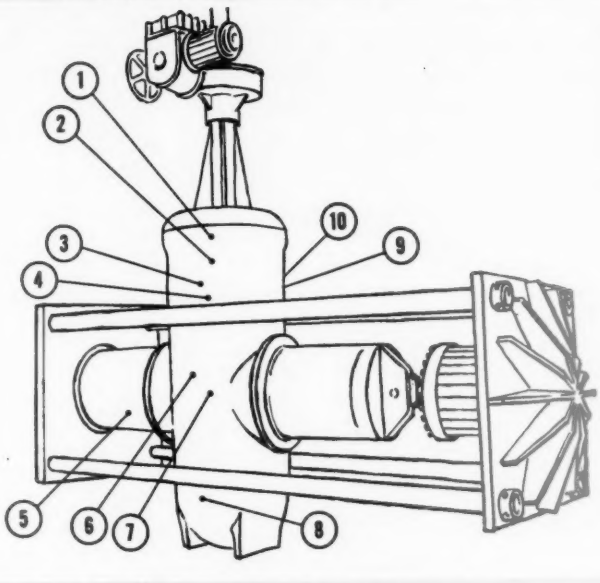

The above sketch shows the placement of the strain gages used in the test.

W-K-M Valves

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FIRST Engine-Centrifugal Unit Designed for Automatic Operation

Initial remote controlled station of this type planned for operation this year on major transmission line*

D. M. Salls

ONE of the most recent developments in the design of compressor units is the engine driven centrifugal compressor. Actually, this unit consists of three elements, each of which has been used for many years in the pipe line industry and perhaps it should more properly be called the development of an application. The prime movers in this case are high output, supercharged gas engines capable of a maximum delivery up to 5000 hp. A step-up gear is required to raise the crankshaft speed to that required by the centrifugal compressor. The step-up gears may be either single or double step designs depending entirely upon the compressor inlet conditions and the compression ratios required. Generally speaking, the larger volumes, above 5000 cfm, can be handled with single step increasers. The centrifugal compressor is similar in all respects to units found in existing stations where they may be driven by a variety of power units including electric motors, steam turbines and gas turbines.

Presently under construction is one of these engine driven centrifugal compressor units for a major natural gas transmission line .The unit will go into service this fall in time to catch the winter load on the line. The engine is a supercharged gas engine[1] rated at 37 bhp at 327 rpm. The maximum speed of the engine is 360 rpm, which is 10 per cent over normal speed, at which the compressor load can be as high as 4500 bhp. The fuel consumption of this engine at full speed is 6200 Btu/bhp/hr. The engine intake air is compressed in a turbo-charger cooled by a water cooled intercooler and then further cooled by a turbo-expander compressor unit to supply the power cylinders with air at about 100 F depending upon ambient conditions. Since the unit will not depend upon evaporation for cooling the air, the make-up water required for the unit will be negligible.

The new unit will require a two step speed increaser drive[2] as the compressor is rated at 5500 rpm at normal speed. The compressor[3] is a single stage unit with overhung impeller and 24-in. ASA 600-lb suction and discharge flanges. Both flanges are on a common centerline at right angles to the axis of the shaft. A cover plate on the front side of the compressor can be removed for access to the impeller and the entire rotating assembly. The outboard main bearing and the thrust bearing can also be removed from the drive end as well.

The low speed coupling is a floating shaft assembly.[4] Coupling sizes and shaft lengths have been carefully investigated for torsional vibration characteristics.

Overall length of the unit from the turbo-charger air inlet flange to the cover plate on the front of the centrifugal compressor is 46 ft 6-in. The pitch spacing of units placed side by side would be 22 ft. Estimated total weight

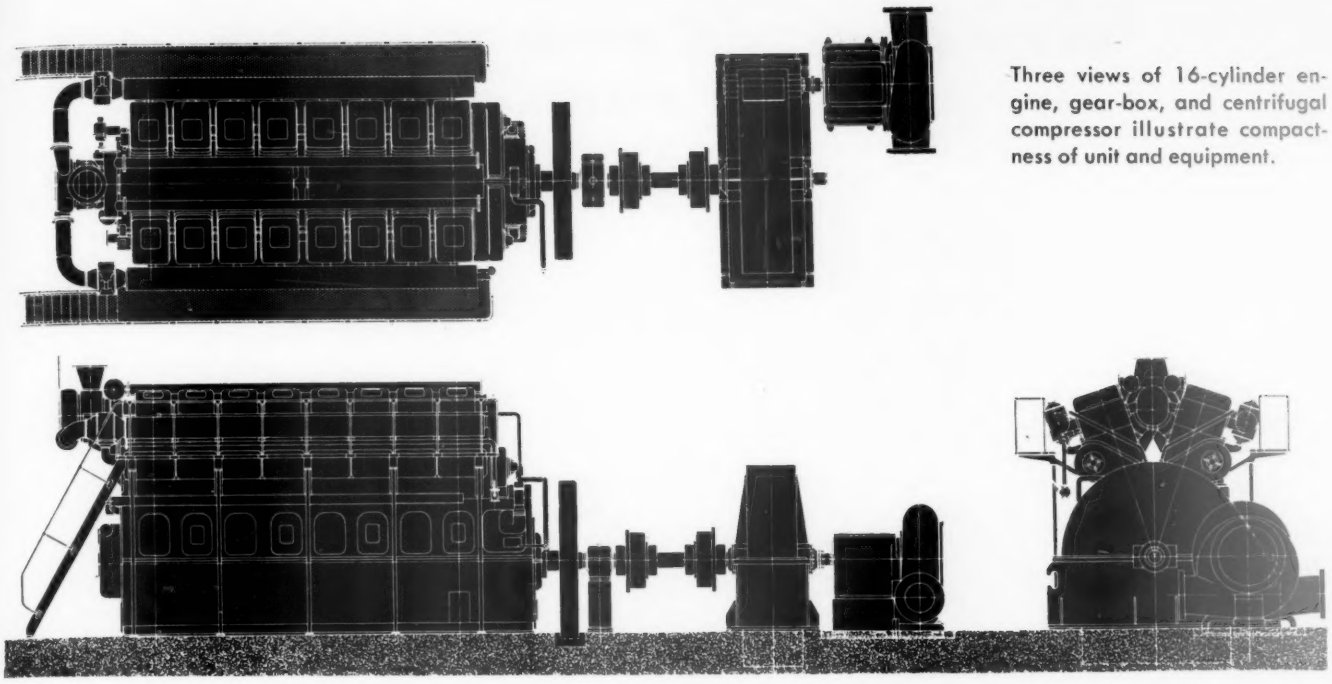
*See "Pipe Line Projects" feature section, this issue.

[1]Cooper-Bessemer LSV-16.

[2]Western Gear Works Model 4525-TS.

[3]Cooper-Bessemer RFB-24.

[4]Thomas 1800-BM



Three views of 16-cylinder engine, gear-box, and centrifugal compressor illustrate compactness of unit and equipment.

of the unit including engine, gear and compressor is 337,000 lb.

Three engine driven pumps are mounted on the forward end of the engine. These pumps are the engine lube oil pump, engine jacket water pump and the circulating water pump to the lube oil cooling system. Since the engine lube oil requirements are different from those of the compressor and gear, there is a separate lube oil pump mounted on the intermediate shaft of the speed increaser drive to supply oil to the gear and compressor. The seal oil pump for the compressor shaft seal is driven from the other end of the intermediate shaft and takes its suction from the pressure supplied by the lube oil pump. A small motor driven auxiliary pump supplies oil to the seal system to permit the shaft to function before the compressor casing is pressurized.

The compressor requires 20 gpm of turbine grade lube oil for the outboard sleeve bearing, thrust bearing and the high pressure shaft seal and inboard bearing. The high pressure seal oil pump takes 5 gpm from the above flow and delivers it to the shaft seal and high pressure sleeve bearing. An overhead emergency seal oil tank vented to the compressor casing floats on the seal oil pump discharge line. This tank has two functions, it supplies seal oil to the seal in the event of a pump failure and due to its elevated position above the compressor, it establishes the differential pressure between the gas pressure in the compressor case and the oil supplied to the seal.

In this particular installation, the bottom of the seal oil tank is 10 ft above the centerline of the compressor shaft and with the normal oil level in the tank a static head differential of 12 ft would be maintained above the gas pressure in the compressor casing. The vent line from the top of the emergency seal oil tank should tap the compressor casing behind the impeller since at this point the seal oil differential pressure will be due to the static head of oil in the emergency seal oil tank. A level control on top of the emergency seal oil tank maintains the oil level in the overhead tank. The control air from the regulator connects to the top of the diagram of a by-pass valve so that the oil level in the emergency seal oil tank is maintained.

Since the seal oil pump delivers about 5 gpm at normal engine speed and the seal normally requires only 1.5 gpm, the excess of 3.5 gpm passes through the by-pass valve and is available for maintaining seal oil pressure under some abnormal leakage condition. A pressure switch is piped into the control air from the regulator on the emergency seal oil tank and connected to alarm and shutdown devices to warn the operator of a low seal oil level and to shutdown the unit automatically when the seal oil level further recesses to the set level for shutdown.

The engine driven centrifugal compressor unit is ideally suited to operation under a supervisory control system wherein the operator pushes a master control switch on a panel board thus, starting a sequence that starts the engine and puts it on the line automatically.

Engine speed can be adjusted manually or an oil relay govenor with a pneumatic head can be used to automatically adjust the engine speed to maintain a set discharge pressure. The next step in automatic operation would be to operate the automatic starting control switch from a distant point such as another compressor station or the company dispatcher's office.

Such a system should require telemetering equipment so that the person operating the compressor unit will have indications of what the engine speeds and line pressures are. Alarm signals should also be transmitted to the remote point of operations so that the operator will have an indication of some malfunction at the station.

The engine driven centrifugal compressor has many economic advantages to offer pipe line operations. Of first

The Author

David M. Salls is application engineer with Cooper-Bessemer Corporation, which he joined in 1942.

A graduate of Pratt Institute and the University of Michigan, he was previously employed by General Chemical Company as an engineering trainee. He is a registered professional engineer and an ASME member.

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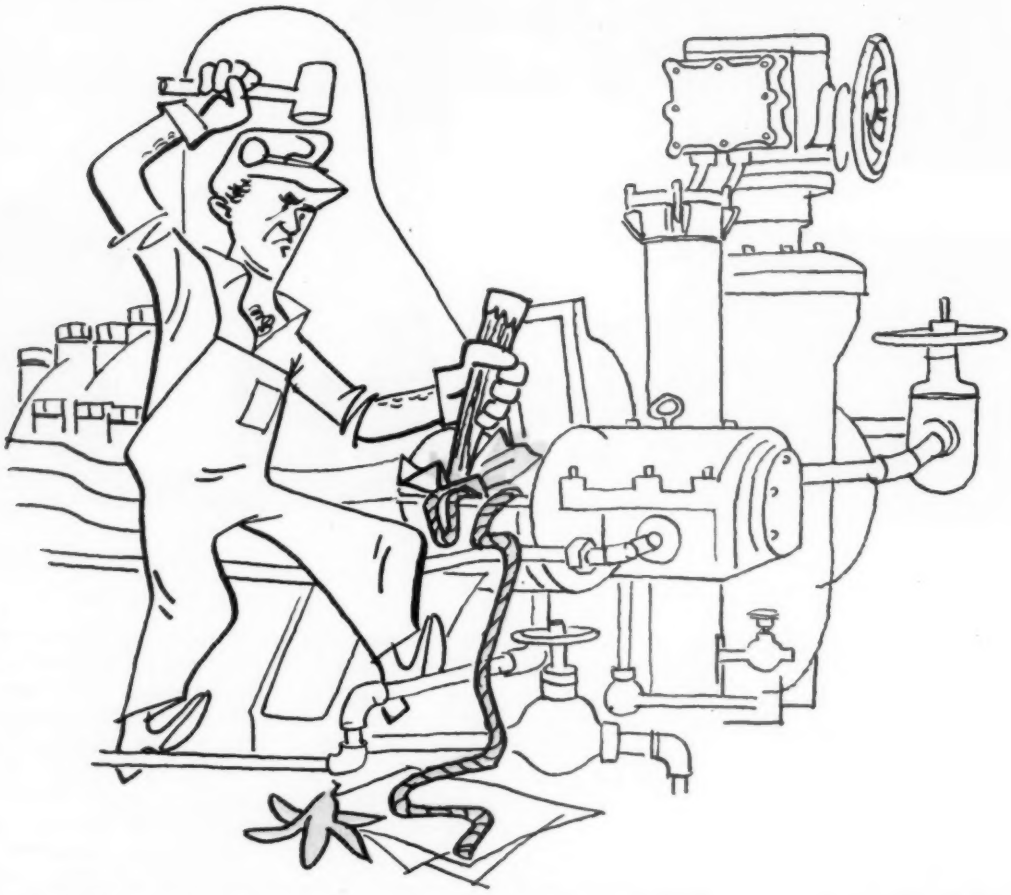

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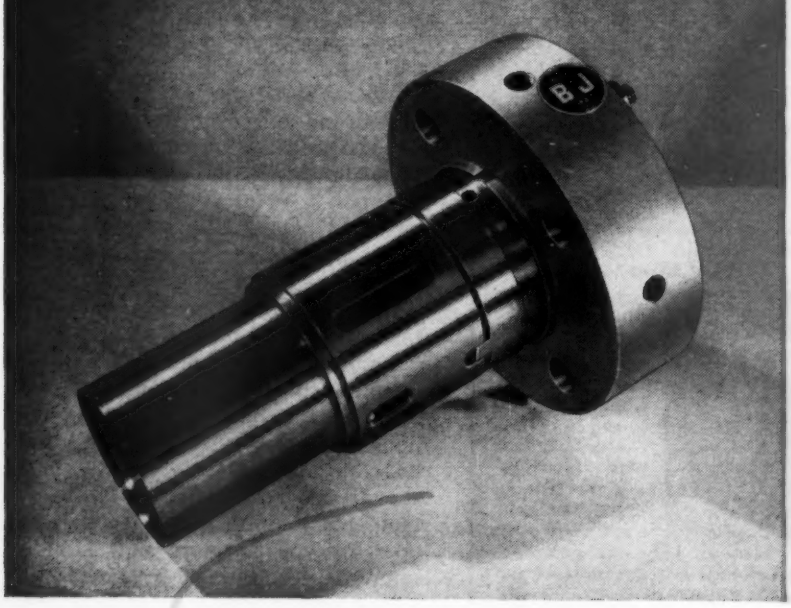

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importance is the advantage of low cost of installation of the unit. Since about 60 per cent of the annual cost of owning and operating a compressor station is in the annual fixed charges, it is apparent that low installation cost is very important. Installed cost of the basic unit including engine, speed increaser drive and compressor has been estimated at approximately $115 bhp. This figure includes freight, air starting equipment, fuel gas equipment, lube oil accessory equipment, cooling equipment including radiators, instrumentation, service piping and concrete foundations. It does not include structures, site, gas piping or engineering costs because these figures vary so widely with different operating companies.

Annual fuel oil cost for operating compressor station equipment is the second most important item in the annual cost of owning and operating the station. Since fuel represents about 15 per cent of the total annual cost, the high thermal efficiency of the supercharged gas engine over a wide range of engine loads offers a considerable saving in annual expense.

Automatic Control System

The automatic control system developed to perform the supervisory station control of the unit described above is based on the use of explosion proof electrical equipment. It is similar to an installation in operation on a reciprocating unit in Northern Natural Gas Company's station at Mullinville, Kansas. (See page D-14, **The Petroleum Engineer,** April, 1955.

The control system employs largely electrical devices as a means of providing fully automatic control of a centrifugal compressor unit. These off unit engine controls can be located on a panel beside the individual engine or can be grouped on panels in a separate control room as desired, depending on the specific station layout. The particular panel shown is based on a station having a common water cooling system for all units, but individual unit jacket water pumps, motor driven.

The design as shown is based on a minimum of operating personnel being required, and provides both visual and audible anticipatory alarms to show conditions departing from normal on services such as lubricating oil and water temperatures and pressures. With the development of satisfactory automatic valve operators for local and remote control, it becomes possible to start and place a centrifugal unit on the line with one operator.

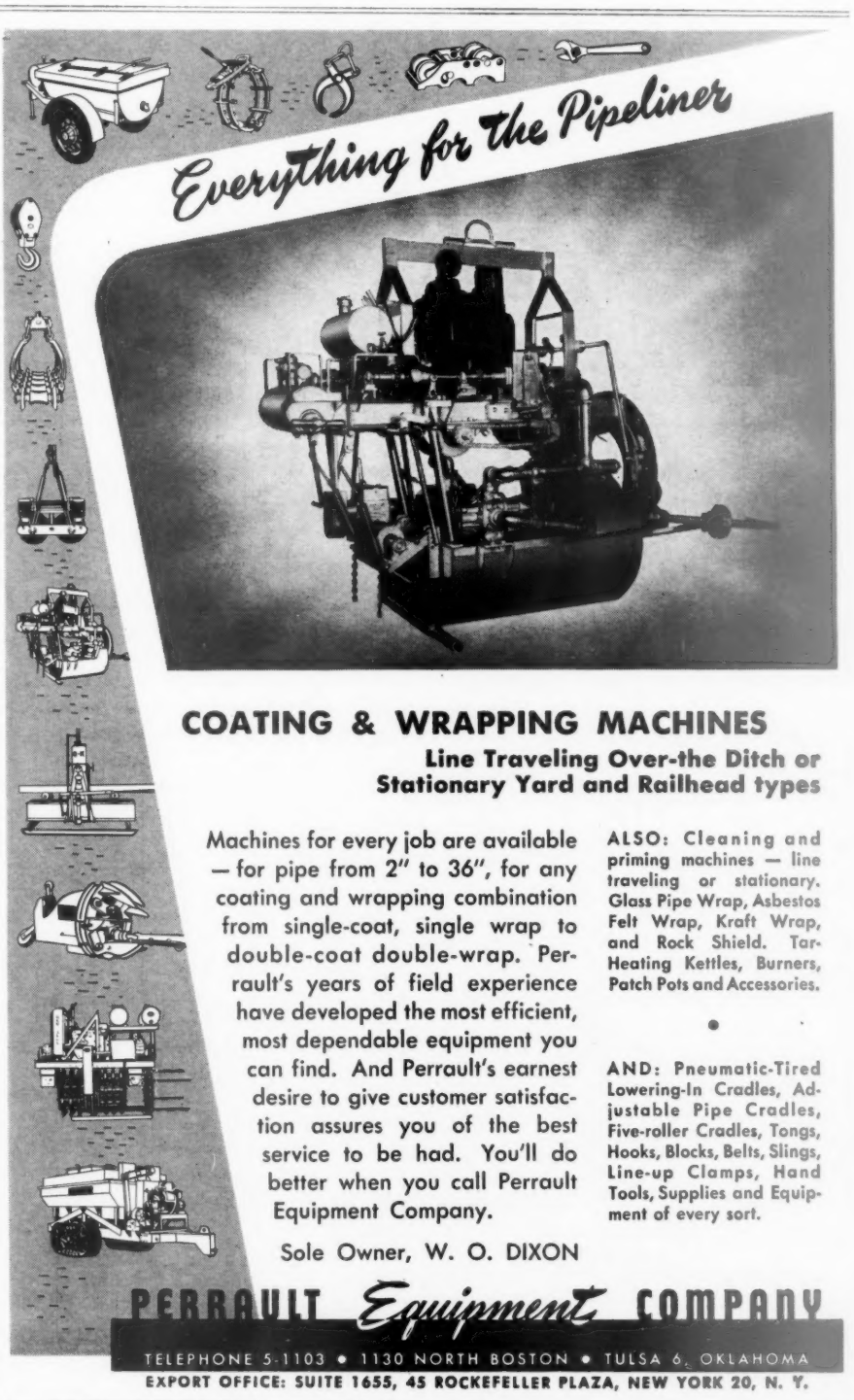
The control system is designed to permit an operator to start a centrifugal compressor unit and place it on the line with the minimum of manual operations combined with the maximum of safeguards. As indicated on the accompanying material, the only manual operations are:

(1) operation of master control switch and
(2) adjustment of the speed if speed change is desired.

The panel provides adequate provisions in the way of indicator lights to determine the location of the valves and tachometer for engine speed. All electrical equipment provided is explosion-proof.

The control system for an individual unit is affected by the general station layout in that fewer controls are involved if the self-contained unitized compressor engine setup is adopted. Some auxiliary power is required around any station for station functions, camp use, air compressors, lighting, etc. With this in mind, it is believed that the provision of a 12 volt d-c control system with charger probably represents a simple and still very dependable control arrangement.

See following pages for control diagram and description →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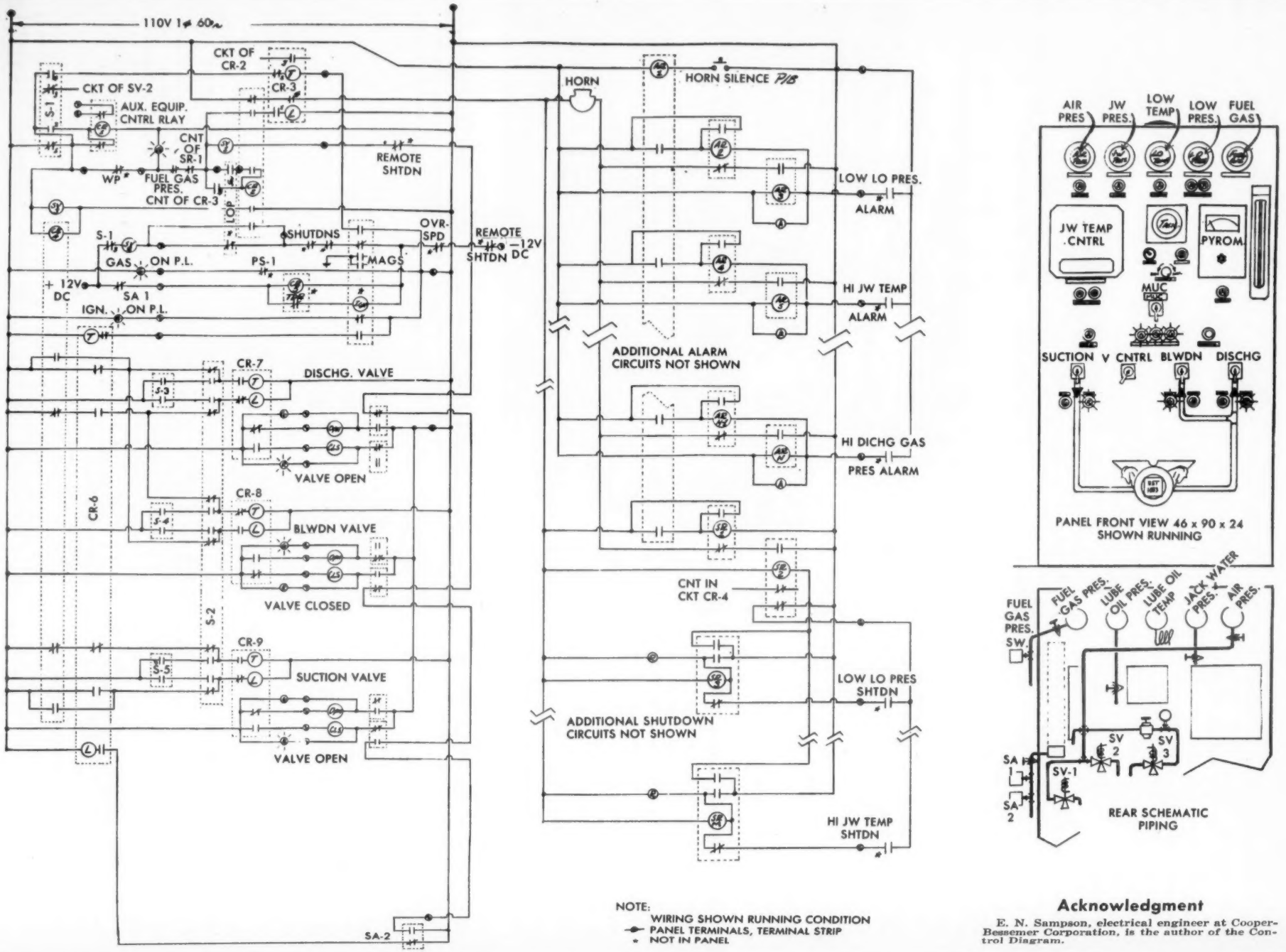


NOTE:
WIRING SHOWN RUNNING CONDITION
PANEL TERMINALS, TERMINAL STRIP
* NOT IN PANEL

PANEL FRONT VIEW 46 x 90 x 24 SHOWN RUNNING

REAR SCHEMATIC PIPING

Acknowledgment

E. N. Sampson, electrical engineer at Cooper-Bessemer Corporation, is the author of the Control Diagram.

Typical Automatic Control of Engine Centrifugal Compressor Station With Motor Driven Auxiliaries

Preparation For Start of Automatic Compressor Station:

1. Check for power to panel.
   a. Discharge valve—green light **on** indicating **valve closed.**
   b. Suction valve—green light **on** indicating **valve closed.**
   c. Blowdown valve—red light **on** indicating **valve open.**
2. Check for fuel gas pressure.
3. Check to insure that:
   a. Valve control is set on **automatic.**
   b. Alarm circuit switch is set in **on** position.

START:

PANEL OPERATION	EQUIPMENT OPERATION
A. Manual Operation:	
1. Manually turn **master unit control** switch to **start** position and release to **run** position.	
B. The Resulting Operations Are All Automatic:	
1. Auxiliary control relay CR-1 closes (Green light for **Aux** comes on). **Holding relay** CR-2 energized.	Water pump starts closing water pressure switch W. P.
2. **Valve control relay** CR-4 energized by **Holding relay** CR-2, energizing, **open circuit** of discharge valve; (Red light comes on indicating discharge valve **open** and green light goes out), **close circuit** of blowdown valve; (green light comes on, red light goes out). Starting **speed** control solenoid SV-3 energized.	Discharge valve opens. Blowdown valve closes.
3. After valves complete travel interlock circuit of starting air solenoid SV-1 completed.	Starting air valve opens and engine rolls, purging air and exhaust systems, building up inlet manifold air pressure.
4. Inlet manifolds air pressure switch SA-1 closes, energizes purging time delay relay, CR-5. After 10-15 seconds time, purging delay relay CR-5 closes, energizing the ignition relay **Ign.** (Green light indicating **ignition on** is lit.)	Following purge period, ignition is turned on.
5. Ignition relay **Ign** energizes gas solenoid SV-2 (Green light indicating **gas on** is lit).	Gas admitted to engine in starting quantity, by automatic gas control valve. Engine starts and accelerates to low speed, coming under governor control. Inlet manifold air pressure and lube oil pressure increases.
6. Inlet manifold air pressure switch SA-2 is activated, de-energizing starting air control circuit through solenoid interlock circuit. SA-2 also operates **valve control relay** CR-6. Relay CR-6 sets up circuits for opening suction valve.	Starting air is shut off.
7. Lube oil pressure switch operated by oil pressure, opens circuit to relay CR-2.	Engine pump has developed normal lube oil pressure, and lube oil shutdown OPS is in normal running position.
8. Release of CR-2 permits governor to take control of engine, brings safety shut downs into circuit, and drops valve control relay CR-2. The running speed is set by means of the speed control knob located on the panel. If the speed at the time the engine was shut down was engine rated speed, then the engine at this time accelerates to rated speed, providing no adjustments have been made with the speed control knob. As an alternate to this manual control of speed, automatic speed and/or unloading controls can be provided if desired.	Engine accelerates to previous running speed setting. Suction valve opens. Engine is now on the line and loaded.
9. Release of CR-4 completes, open circuit of suction valve (red light **on,** green light **out**).	Suction valve opens.
10. Engine on line pumping gas.	

STOP:

When shutting down, turn **master unit control** switch to **stop.** Engine will immediately shut down in the following manner:

1. **Gas solenoid** SV-2 immediately closes shutting off the gas.
2. The ignition is maintained while the gas engine is still turning from momentum.
3. As the inlet manifold air pressure falls, inlet manifold air pressure switch SA-2 operates causing the discharge and suction valves to **close,** and blowdown to **open** through circuits of **valve control relays** CR-4 and CR-6.
4. Further decrease in inlet manifold air pressure results in releasing ignition relay **Ign.**
5. The engine is now down and all relays and their contacts, including lights, are in the position described prior to **starting.**

Relay CR-3 is a **cutout** to de-energize the shutdown circuits when unit is stopped. This relay holds the shutdowns out for starting, allows shutdowns to **come in** after engine is running.

The control circuit as shown, was developed for 110 v., 60-cycle control voltage, however, other voltages may be used. The parts used in the circuit are standard manufactured parts available from several different relay manufacturers.

E. N. Sampson, electrical engineer at Cooper-Bessemer Corporation, is the author of the Control Diagram.

WIRING SHOWN RUNNING CONDITION
PANEL TERMINALS, TERMINAL STRIP
NOT IN PANEL

SA-2

XUM

Pipe Line Projects

Work Starts on Magnolia Pipe Line in Texas

Work has begun on 215 miles of crude oil pipe line for Magnolia Pipe Line Company between Midland and Corsicana, Texas. The system will be 12, 14, and 16-in. diameter pipe.

Contracts have been let to H. B. Zachry Company and O. R. Burden Construction Company. Zachry is working from the Corsicana end and Burden from Midland. Work should be completed in October.

Magnolia has an existing 12-in. line, which is partially looped, between Corsicana and Midland.

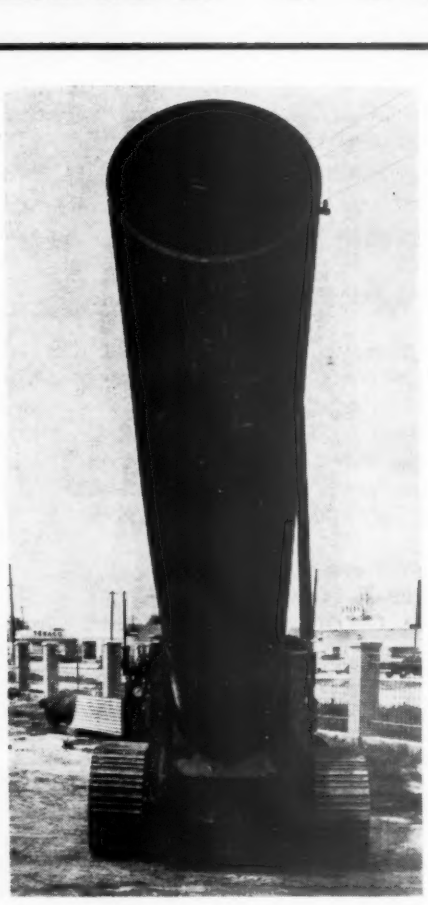
Revised Welding Standards Manual Announced

Publication of a third edition of the "Tentative Standard for Field Welding of Pipe Lines," incorporating certain changes resulting from comments on the second edition issued in February, 1954, has been announced by the API.

Principal changes are in the welding section where rather extensive revisions have been made. The important additions to this revision are the Procedure Qualification requirement and sketches of test specimens.

The Standard and its latest revision were prepared by a committee on which serve representatives from the American Gas Association, Pipe Line Contractors Association, Pipe Manufacturers, and the American Petroleum Institute. The American Welding Society and the Society for Nondestructive Testing now have official representation on this committee.

Copies of "API Standard 1104, Third Edition, Tentative Standard for Field Welding of Pipe Lines," may be ordered from J. A. McNally, American Petroleum Institute, 50 West 50th Street, New York 20, New York. The price is 50 cents per copy.



Big Bertha Howitzer? No—front view of the first vertical hydraulic pipe bender ever built. The machine, designed for interchangeable bending sets for cold smooth bending of pipe from 16 through 30-in. diameter, is built by Cinch Pipeline Equipment, Inc., 7020 Long Drive, Houston, Texas. The overall width of the new machine has been held to 7-ft, 5-in. Weight is about 27,500 lb with tracks and bending set mounted. A special design for 36-in. pipe has also been constructed, with a 7-ft, 9-in. width with tracks. Either type can be moved cross-country on its tracks.

Cities Service Plans Pipe Lines in Oklahoma, Kansas

Permission to construct a 93-mile pipe line between Blackwell, Oklahoma, and Independence, Kansas, has been requested of the Federal Power Commission by the Cities Service Gas Company.

Also included in the application is requested permission for a 145-mile gathering system in Barber County, Kansas, and Woods County in Oklahoma.

The pipe lines, ranging in size from 4 to 20 in., will cost an estimated $2,961,500 and deliver gas into a 26-in. line near Alva, where a 2700-hp compressor station, costing $753,000 will be built.

Glenn W. Clark, president of the company, said the new construction will make additional volume of gas available to meet higher peak day demands.

New Laboratory. In operation at Joliet, Illinois, is this new laboratory of Natural Gas Pipe Line Company of America and Texas-Illinois Natural Gas Pipe Line Company. The new, modern unit replaces similar limited facilities in operation since the beginning of operations of the Natural system. Of brick construction, the lab has two offices, balance room, reception room, laboratory and ample storage and utility space. It will perform a multitude of services for the system's three operating companies, including Natural Gas Storage Company of Illinois. New building is pictured at left; interior of lab showing low temperature fractional distillation equipment shown at right.

Major Line Extension to Be Made by Saskatchewan Power

Major extension of the Saskatchewan Power Corporation natural gas pipe line system in the north central part of the province are to be laid this summer in order to provide more gas for the city of Saskatoon and new service for the city of Prince Albert and the town of Biggar, in the same general region. Supplies are to be drawn from the expanded Brock-Coleville composite gas cap, which now serves the pipe line from Brock to Saskatoon, 102 miles in length. This line was laid in the summer of 1953.

The first phase involves construction of a 14-in. pipe line from Coleville to Saskatoon, via Biggar, a total of 115 miles. This line will act as a loop of the existing line, as well as providing new service for intermediate towns along its route, The second phase will consist of 10 and 12-in. lines, totaling about 125 miles and extending from Saskatoon to Prince Albert by way of a number of small towns on the route.

The corporation now has some 7000 services operating in Saskatoon, and, although it has made no official estimate of the potential for the expanded system, a figure of an additional 5000 to 6000 services for connection this year and next appears reasonable.

The closing date for tenders was set May 4, with a requirement for completion of construction by October 1 at the final destination in Prince Albert. Assuming a normal construction season, without unusual interruption due to average wet weather, the entire job should be capable of completion within the time limit using two spreads. This is the only major project certain of being carried out in the current construction season and bidding is understood to have included all the pipe line contractors operating in Western Canada.

Products Line Planned For Iran; Contracts Awarded

The National Iranian Oil Company has awarded contracts for construction of a 573-mile, 10-in. products pipe line from Ahwaz to Teheran, Iran, beginning in September. The system will cost $32,000,000 to build and will have a capacity of 40,000 bbl a day. Source of the products will be the Abadan refinery.

To Costain-John Brown, Ltd., London, went the contract to construct the southern section, 337 miles that will cost $18,200,000. On this section the Zedran Mountains will be crossed at an elevation of 10,000 ft.

The firm of Entrepos, Paris, will lay the northern 236 miles, costing $14,000,000.

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United States Steel's Consolidated Western Steel Division's new steel pipe manufacturing plant near Provo, Utah, last month began producing large diameter, high strength expanded line pipe. Equipped to manufacture pipe in sizes from 20 to 36-in., the new plant is on a 117-acre site across the street from the Geneva Works of U. S. Steel's Columbia-Geneva Steel Division. Machinery for the manufacture of the large diameter pipe is installed in the 175,000-sq ft main building of the plant, which will have five acres under roof when construction of all buildings is completed later this year. Pictured above is the main building with its twin 980-ft bays. The mill's large diameter pipe production line is now operating in one bay, while the second is being readied for the installation at an early date of machinery for the manufacture of small diameter, resistant-weld line and water pipe in sizes from 4 to 12¾ in. A 300-ft shipping bay and an 180-ft receiving bay make up the rest of the main building.

Westcoast Wants to Begin Construction This Summer

Westcoast Transmission Company, Ltd., has asked permission of the Canadian government to change its capitalization in order that it may begin construction this summer on its 650-mile gas line. Being sought is a change in its authorized capitalization from the present 5,000,000 no-par shares to 25,000,000 shares at $2 par value. Company officials say this refinancing is necessary because cost of the pipe line as now planned is much greater than as originally proposed.

As now designed the system will extend from the Peace River area to a point near Sumas, Washington, where it will connect with Pacific Northwest Pipe Line Corporation's trunk line from the San Juan Basin.

Present plans are for delivery of gas to the Vancouver area by July, 1957, and completion of the system to its terminus at Sumas by November 1, 1957. It will be constructed of 30-in. pipe and will have an initial throughput of 370,000,000 cu ft a day. Of this volume 300,000,000 cu ft will be delivered to Pacific Northwest for consumption in the United States and 70,000,000 cu ft will be marketed in British Columbia, principally the Vancouver area.

In addition to the main line, there will be 225 miles of 8 to 26-in. gathering lines.

Canadian Bechtel, Ltd., is doing the engineering work and will supervise construction.

Gulf Interstate to Install Robot Station

Gulf Interstate Gas Company has received FPC approval to construct an experimental remote controlled, unattended booster compressor on its system near Stanton, Kentucky. The new station, to be controlled from the firm's present Clementsville, Kentucky, station, 80 miles away, will be the first of its kind in the gas transmission industry.

Outstanding feature will be the installation of a 3700-hp 16 cylinder, V-type, 4-cycle, turbocharged, vertical gas engine driving a centrifugal compressor through a speed increaser. (See article on Page D-54, this issue, for further description.)

Company officials say the station will be tested over a 15-month period to determine the practicality of the operation. Cost of the station is estimated at $730.000.

If the experiment fails, the company expects to salvage $450,000 of the initial cost.

Gulf Interstate's Stanton station is uniquely first in that it will be the first engine-centrifugal station designed for fully automatic operation from a remote control point. No attendant will be needed at the station. The station, however, is the second to be announced that will use an engine-centrifugal unit. A similar installation will be made this summer by Transcontinental Gas Pipe Line near Houston, Texas. (See page D-77, *The Petroleum Engineer*, May, 1955.)

TGT Asks FPC Okay For $56 Million in Projects

Tennessee Gas Transmission Company has propsed to the FPC that it build $56,000,000 in pipe line and compresor facilities, including an extension of its gas gathering system into southeast Louisiana and Mississippi River delta areas.

Capacity of the company's natural gas transmision system would be hiked to 1,800,000,000 cu ft daily and to 2,180,000,000 cu ft on peak days by construction of the new facilities. They would be used to increase sales to new and existing customers along the system from Mississippi to Massachusetts by 148,000,000,000 cu ft daily.

In Kentucky and Ohio, 221 miles of 30 and 26-in. pipe would be laid parallel to the existing pipe line system, and 12,540 hp would be added at new and existing compressor stations.

New stations would be built with 4400-hp each year near Winnsboro, Louisiana, and New Albany, Mississippi; 2640-hp would be added to the company's existing station near Kinder, Louisiana; and authorization was sought for an additional 1100-hp at an authorized but as yet unbuilt station near Findley Lake, New York.

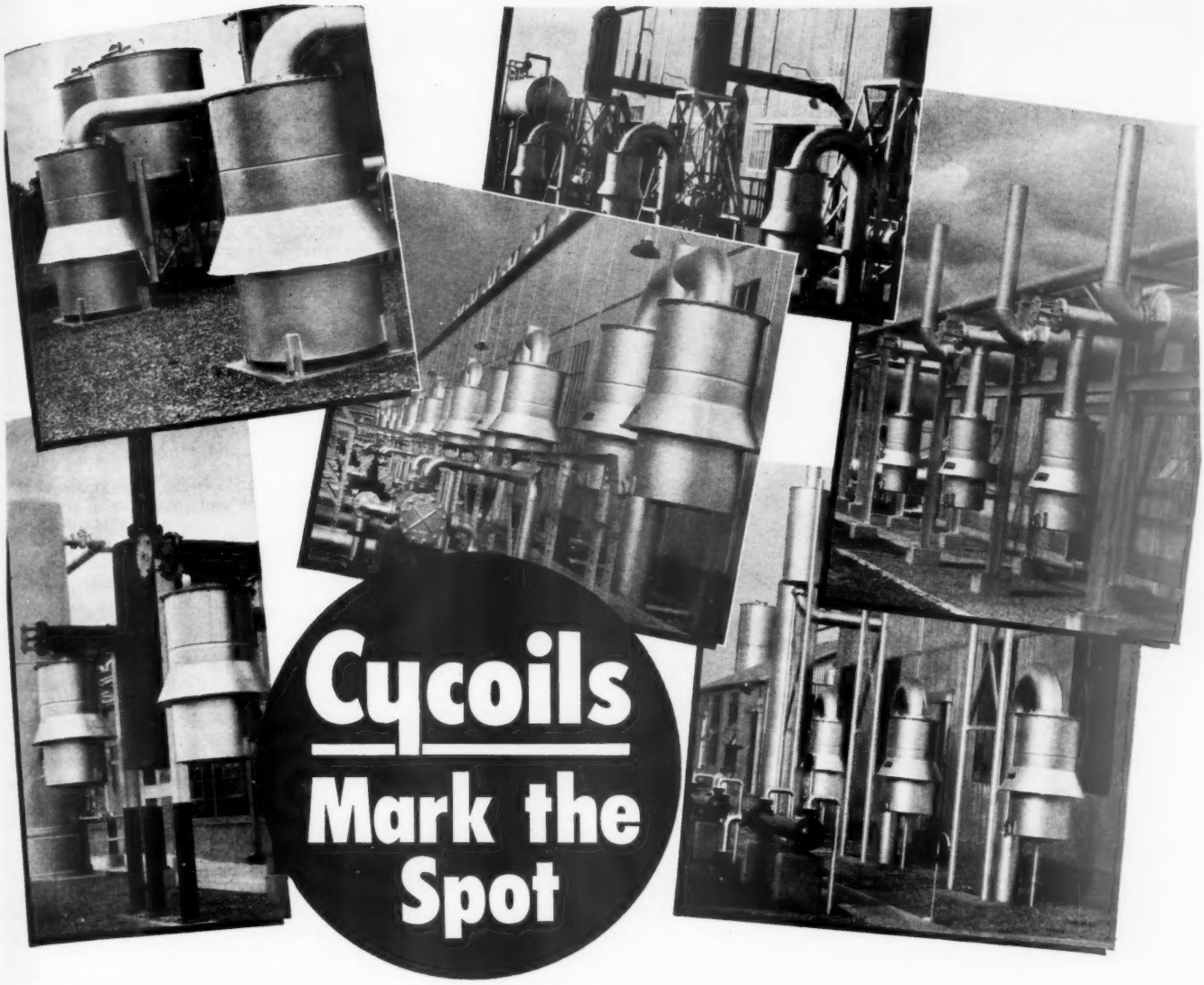
New gas reserves to be made available by extension of the gathering system would support the additional sales and also reinforce the company's over-all gas supply position. Made part of the application were 87 gas supply contracts with 57 producers in 64 Louisiana and Texas fields.

Approximately 376 miles of gas gathering line, ranging from 6 to 24-in., are planned in Louisiana and Texas.

Revised Piping Code Released to Industry

A revised Section 8 on Gas Transmission and Distribution Piping, ASA B31.1, dealing with gas industry piping systems has just been released by the American Society of Mechanical Engineers.

The new section of the American Standards code has been approved by the American Gas Association board of directors, the ASME Board of Codes and Standards, and the American Standards Association. It establishes safe standards in the design, fabrication and installation of gas transmision and distribution pipe line systems. It also covers the safety aspects of inspection, operation, and maintenance of gas pipe lines. Included also under the new Section of the Code on Pressure Piping are gas compressor stations, gas metering and regulation stations, gas mains and gas services up to the customer's gas meter.



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PIPE LINE PERSONALS

John Kirtley

W. L. Stanton

V. M. Meythaler

W. M. Elmer

Kenneth R. Knapp has retired from the AGA laboratories after 44 years of service in the gas industry. He was active in the development of the American Standard for installation of gas piping and gas appliances in buildings, serving on the committee since its inception in 1925. A 1911 graduate of the University of Pennsylvania, Knapp was employed by United Gas Improvement Company, Philadelphia, for 12 years and was later with Philadelphia Gas Works Company. In 1929 he joined the AGA laboratories staff at Cleveland, Ohio.

Robert G. Bushnell has been elected vice president and treasurer of the Buckeye Pipe Line Company, it is announced by **George S. Patterson,** president.

John M. Wilson, director of employee relations, United Fuel Gas Company, Charleston, West Virginia, was elected chairman of the Great Lakes Personnel Conference of the American Gas Association at a meeting held in Chicago. Also elected officers of the conference for the coming year were **W. E. Hoare,** employee relations director, The Ohio Fuel Gas Company, Columbus, vice chairman; and **Emory A. Manlove,** assistant to the vice president of the Peoples Gas Light and Coke company, secretary for the coming year.

W. M. Elmer has been appointed senior vice president in charge of financing, sales, gas supply, production, and FPC regulation for Texas Gas Transmission Corporation. **John Kirtley** has been elected vice president in charge of public and employee relations for the company. **W. L. Stanton** has been elected vice president in charge of gas supply. **V. W. Meythaler** has been elected treasurer to succeed Elmer.

Dennis L. Newberry of Livermore, Kentucky, division safety manager for Texas Gas Transmission Corporation since last September, has been appointed to the newly-created position of sales representative in the company's sales and customer relations department.

Glover H. Cary, Jr., Owensboro, Kentucky, who has been a foreman in the company housing department since July, 1952, has been named to the position of safety engineer and assigned to the safety division III area formerly covered by Newberry.

A. L. Vaughan, superintendent of Northern Natural Gas Company compressor stations, has been re-elected to the board of directors of the Natural Gasoline Association of America for a term of three years. He has just completed serving a one year term as director. Vaughan is in direct supervision of compressor facilities of Northern and its subsidiary, Permian Basin Pipeline Company. These facilities include 33 compressor stations and 15 processing plants located in New Mexico, Texas, Oklahoma, Nebraska, Iowa, and Minnesota.

Frank D. Gardner, Sinclair Crude Oil Company, is a new member of The Pipe Liner Club of Tulsa, Oklahoma.

Buckeye Pipe Line Schedules Three Projects

The Buckeye Pipe Line Company has scheduled the following projects for completion during 1955:

An existing 8-in. crude line is to be reconditioned and made suitable for products service from Toledo to Cleveland, Ohio. A new pump station will be built at Toledo together with necessary tankage and additional pumping equipment installed at Wakeman Station, Ohio. At Toledo products will be received from the system of the Wolverine Pipe Line Company and also from refineries in this area for delivery to shippers terminals at Cleveland. To be finished October 1, 1955.

Construction of a 14-mile 10-in. crude line from the Wayne Station of Buckeye's system in Michigan to Detroit. To be completed October 1, 1955.

Extension of Buckeye's Midwest products system from Lima, Ohio, to the vicinty of Ft. Wayne, Indiana, for the handling of products originating at Toledo. To be finished by the end of the year.

Southeastern Saskatchewan Crude Oil Lines Planned

Several new companies are applying for Parliamentary incorporation at Ottawa with a view to seeking permission to build a crude oil pipe line from the southeastern Saskatchewan fields to a junction point on the Interprovincial Pipe Line company system. The most likely connection is Cromer pumping station in western Manitoba, immediately south of the Daly oil field.

The companies seeking incorporation include Westspur Pipe Line Company, which would be a wholly owned subsidiary of Imperial Oil; S & M Pipe Line Compay Ltd., affiliated with Canadian Devonian Petroleums Limited, a substantial holder of freehold oil and gas rights in southeastern Saskatchewan and a large joint operator in the Frobiher field; and Trans-Prairie Pipelines Ltd., a Manitoba company.

Mos of the aplicants propose to construct about 100 miles of 8-in. or 10-in. line and, if successful early enough this year, would try to have the line in the ground by next fall.

Pacific Coast Gas Association Convenes

On May 2-3 the Pacific Coast Gas Association conducted its annual conference on Gas Supply and Transmission at the El Mirador Hotel in Palm Springs, California. J. A. Millan, Southern Counties Gas Company, was sponsor of the conference,while Frank R. Bater, San Diego Gas and Electric Company acted as general chairman.

New. The Cat D9 tractor, sixth machine in Caterpillar's crawler line, is a 230-drawbar horsepower turbocharged tractor resulting from 10 years of big tractor research and development. Thoroughly field tested during 1954, when Caterpillar put ten D9Xs on various jobs from coast to coast, it is expected that the 56,000-lb machine will have construction applications.

Southern Pacific Pipe Line Contracts Awarded

Contracts for construction of part of the Southern Pacific Pipe Lines, Inc. 800-mile products pipe line system between El Paso and the Los Angeles area have been awarded.

River Construction Corporation, Fort Worth, will build a 150-mile 8-in. section between El Paso and Lordsburg, New Mexico, along the Southern Pacific Railroad tracks.

R. H. Fulton and Company, Lubbock, has contract for 150 miles of 8-in. between Lordsburg and Tuscon, Arizona.

Remainder of the system will be contracted later. Construction is to begin immediately on the first 300 miles.

Texas Eastern Contracts Awarded on New Line

Four contractors have been awarded work on six sections of Texas Eastern Transmission Company's 382-mile, 30-in. Beaumont to Kosciusko, Mississippi natural gas line. The new line will replace "Little Inch" being removed from gas service and planned for conversion to products transportation.

Awards made included Houston Contracting Company, section I, 59 miles of 30-in. between Beaumont and Gillis, Louisiana. Sections II and III awarded to Williams Brothers, Tulsa, 120 miles of 30-in. between Gillis and the Mississippi River. Sections IV and V, awarded to H. C. Price Company, Bartesville, Oklahoma, 134 miles of 30-in. from the Mississippi River to Jackson, Mississippi. Section VI was awarded to H. B. Zachry, San Antonio, 67 miles of 30-in., Jackson to Kosciusko, Mississippi.

Pacific Northwest Line Construction Awarded

First phase of Pacific Northwest Pipeline Corporation's gas pipe line construction program is underway with awards made to six contractors for work totaling 555 miles of the planned 1466-mile system. Cost of the first 8 sections of 22-in. pipe totals $11,236,000.

Awards included:

River Construction Corporation, Fort Worth, Texas. Two sections of 26-in. totaling 150 miles between Ignacio and Moab, Utah.

R. H. Fulton and Company, Lubbock, Texas. Two sections of 26-in. totaling 160 miles between Moab and Jensen, Utah.

Associated Pipe Line Contractors, Inc., Houston, Texas. One section of 26-in., 77.6 miles between Jensen and Green River Wyoming.

A. J. Curtis Construction Company, Casper, Wyoming. One Section of 22-in., 82.8 miles from Greene River to Sage, Wyoming.

B & M Construction Corporation, Oklahoma City, Oklahoma. One Section of 22-in., 90 miles, between Sage and Lava Hot Springs, Idaho.

Midwestern Constructors, Inc., Tulsa, Oklahoma. One section of 22-in., 95 miles, between Lava Hot Springs and Burley Idaho.

Another gas pipe line system that will connect with Pacifiic Northwest, a 380-mile, 22-in. line, to be built by Colorado Interstate Gas Company, is also scheduled for construction this summer. One section of the line, 126 miles, has been awarded to Houston Contracting Company, Houston, Texas. The section is between Denver and Laramie, Wyoming.

WITH THE PIPE LINE CONTRACTORS

● **Arey Construction Company, Box 1501 Pampa, Texas.** Has 100 miles 6-in for *Shamrock Oil and Gas Company*. Amarillo to Lubbock, Texas. H. V. Gorman, superintendent.

● **Baughman Contracting Company, Box 569, R. D. #1, Cumberland, Maryland.** Has large amount various sizes for *Manufacturers Light and Heat Company, West Virginia Natural Gas, and Cumberland and Allegheny Gas Company*.

● **Vaughn & Taylor Construction Company, Inc., Box 2624, Odessa, Texas.** Has 265 miles of 3, 4, and 6-in. products line in Kansas and Oklahoma for *Okan Pipe Line Company* (subsidiary of Warren Petroleum Company, Tulsa).

● **Houston Contracting Company, 2707 Ferndale Place, Houston 6, Texas.** Has 65 miles of 12-in. products line for *Shell Pipe Line Corporation*, Baton Rouge to Norco Refinery (New Orleans), Louisiana. Job resumed and underway after delay due to right-of-way acquisition. Also has 84.8 miles of 36-in. (with H. C. Price Company) in Alabama and Georgia for *Transcontinental Gas Pipe Line Corporation*. Also has 14 miles of 20-in. for *Texas Gas Transmission Corporation* near Minden, Louisiana. Has 126 miles of 22-in. for Colorado interstate Gas Company from Laramie, Wyoming, to Denver, Colorado. No starting date.

● **R. H. Fulton & Company, Box 1526, Lubbock, Texas.** Has 55 miles of 30-in. steel water line for *City of Colorado Springs, Colorado*. Has 137 miles of 6-in. for *Okan Pipe Line Company* (subsidiary of Warren Petroleum Company, Tulsa) from Tulsa to Cushing and westward in Oklahoma to Enid and Helena.

● **Bannister Construction, Ltd., 409 Northern Hardware Building, Edmonton, Alberta, Canada.** Has 72,000 ft of 3-in. flowline system for *Tidewater Associated Oil Company* in Shaunavon, Saskatchewan district. These are surface lines, to be buried when weather permits. Has 20 miles of 3, 4, and 6-in. for *Royalite Oil Company, Ltd.*, in Coleville-Smiley field in Saskatchewan, underway.

● **Gragg, Canada, Ltd., 295 Kipling Ave. South, Toronto 18, Ontario.** Has two 16-in. river crossings on Red River south of Winnipeg for *Winnipeg and Central Natural Gas*. Also approximately 2 miles of 12-in. loop line for *Consumers Gas Company* in Toronto.

● **Missouri Valley Dredging, 22 William Street, Omaha 8, Nebraska.** Has take-off facilities from Harbor Pipe Line at Trenton, New Jersey, for *Sinclair Pipe Line;* 4 miles of 8-in. at Trenton for *Gulf Oil*, and river crossing at McConnellsville, Ohio, for *Tennessee Gas Transmission*, 1254 ft of 26-in.

● **Panama-Williams Company, Melrose Building, Houston, Texas.** Has 36 miles of 30-in. and 31.4 miles of 36-in. in South Carolina and North Carolina for *Transcontinental Gas Pipe Line Corporation*. W. H. Shiflett, superintendent; Lloyd Evans, assistant superintendent; Hank Scherer, office manager.

● **Williams-Austin Company, Grant Building, Pittsburgh 19, Pennsylvania.** Has 31 miles of 26-in. loop gas lines in West Virginia for *Atlantic Seaboard Corporation*. Warehouse at Buckhannon, West Virginia; Ed Peters, general superintendent, Ralph Gaddy, spread superintendent.

● **O. R. Burden Construction Corporation, 6702 East 21st, Tulsa, Oklahoma.** Has 31 miles of 30 and 36-in. in Louisiana for *Transcontinental Gas Pipe Line Corporation*. Also has 120 miles of 12 and 14-in. between Midland and Corsicana, Texas, on looping project for *Magnolia Pipe Line Company*. Bob Jones, superintendent.

● **H. L. Gentry Construction Company, Box 32, Perrysburg, Ohio.** Has 18 miles of 20-in. in West Virginia for *United Fuel Gas Company*.

● **H. B. Zachry Company, Box 2570, San Antonio, Texas.** Has 90 miles of 12 and 16-in. loops for *Magnolia Pipe Line Company*, eastern section of the firm's Midland-Corsicana system. A. "Pup" Vaughan, general superintendent.

● **Midwestern Constructors, Inc., 402 North Boulder, Tulsa, Oklahoma.** Has 14.5 miles of 30-in. and 53.5 miles of 36-in. in Alabama for *Transcontinental Gas Pipe Line Corporation*.

● **Western Constructors, Austin Texas.** Has 76.8 miles of 36-in. in Georgia and South Carolina for *Transcontinental Gas Pipe Line Corporation*.

● **Pipe Line Contracting and Drilling Company, P. O. Box 165, Lemoyne, Pennsylvania.** Has 46 miles of 26-in. in three loops in West Virginia and Maryland for *Atlantic Seaboard Gas Corporation*.

● **Engineering-Construction Company, 402 North Cheyenne, Tulsa, Oklahoma.** Has 150 miles, 6 to 10-in. gas line for *Southeast Alabama Gas District*. Two spreads: Gene Coulter, superintendent at Eufaula, Alabama, and Jim Williams, superintendent, Headland, Alabama.

● **Merritt-Chapman & Scott Corporation, 260 Madison Avenue, New York 16, New York.** Has 53 miles of 8 to 24-in. between Bombay and Butcher Island for *Bombay Port Trust, India*. Also 16 miles of 16-in. between refinery and Sydney for *Australian Oil Refining*.

● **Foster-Wheeler Corporation, 165 Broadway, New York 6, New York.** Has overall supervision of a 1920-mile NATO pipe line system in Europe.

● **B&M Construction Corporation, Oklahoma City, Oklahoma.** Has contract for construction of 500 miles of 12-in. products line from Cadiz to Zaragoza, Spain, for *U. S. Navy* as part of joint venture. A. C. Montin, project manager, in care of Hilton Hotel, Madrid, Spain. Job to start June 1, 1955.

● **Mannix, Ltd., 332 7th Avenue West, Calgary, Alberta, Canada.** Has 100 miles of 3 through 10-in. gathering system for *Pembina Pipe Line Company*. George Hupp, manager; field office at Drayton, Valley, Alberta.

● **Modern Welding Company, Box 528, Owensboro, Kentucky.** Has 112 miles of 6 through ¾-in. for *Southeast Alabama Gas Corporation* in cities of Seale, Newville, Abbeville, Headland, and Eufaula, Alabama; 55 miles of 6 through ¾-in. for *City of Flora, Illinois;* 25 miles of 12 through ¾-in. for *Gas Light Company* of Columbus, Georgia; and 12 miles of 6 through ¾-in. for *Alabama Gas Corporation* in Gadsden, Alabama.

● **Oklahoma Pipe Line Constructors, 6612 Harry Hines Boulevard, Box 13227, Dallas, Texas.** Has 115 miles of 24-in. between Mansfield and Lackawaxen, Pennsylvania, for *Tennessee Gas Transmission Company*. N. L. "Cajun" Arie and Guy Craft, superintendents at Honesdale and Troy, Pennsylvania.

● **Williams Brothers, National Bank of Tulsa Building, Tulsa, Oklahoma.** Has 160 miles of 6-in. for *Bolivian government*, oil line. Has 115 miles of 30-in. between Toledo and Cleveland, Ohio, for *East Ohio Gas Company*. Has 72 miles of 30-in. in Virginia for *Transcontinental Gas Pipe Line Corporation*.

● **Engineers Limited Pipe Line Company, 225 Bush Street, San Francisco, California.** Has 37 miles of 16 and 20-in. in Washington for *Trans Mountain Oil Pipe Line Company*.

● **H. C. Price Company, Box 1111, Bartlesville, Oklahoma.** Has 35 miles of 26-in. loops in Ohio and Pennsylvania for *Tennessee Gas Transmission Company*. Also has for *TGT* approximately 18 miles of 24-in. connecting Harrison and Hebron Storage fields and 50 miles of mainline, 24-in. Also has 77 miles of 26-in. in western Kentucky and Tennessee in six main line loops, plus 72 miles of 12-in., 37 miles of 10-in. and 5 miles of 8-in. in Indiana, for *Texas Gas Transmission Corporation*.

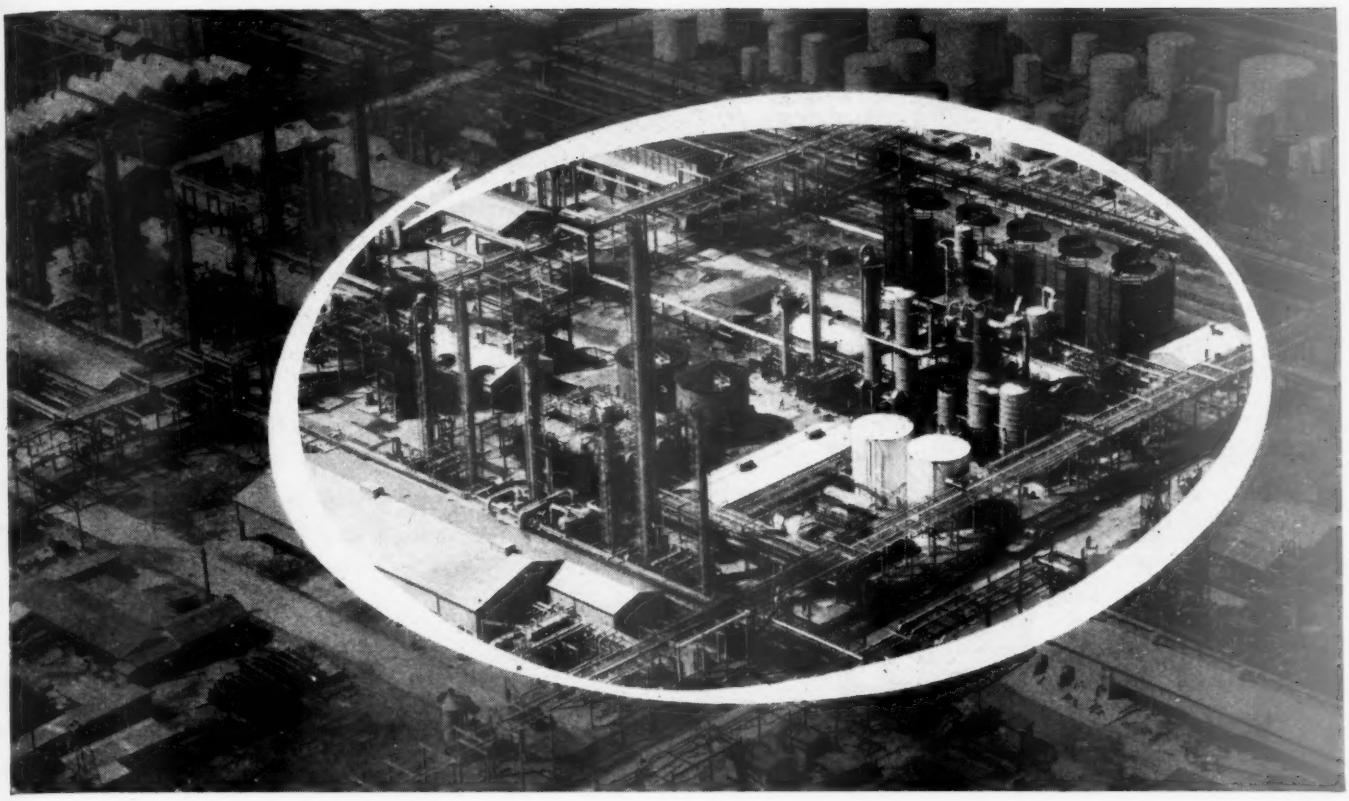
● **Hallmac Construction Company, 2261 West Holcombe, Houston, Texas.** Has approximately 100 miles of 10-in. for *South Georgia Natural Gas Company*.

● **Buchanan Pipe Line Construction Company, Birmingham, Alabama.** Has 80 miles of 6 and 8-in. for *South Georgia Natural Gas Company*.

● **Cumberland Contracting Company, Monticello, Kentucky.** Has approximately 225 miles of 2 through 10-in. for *Southeast Alabama Gas District*.

● **Mid States Construction Company, Box 417, Mt. Vernon, Illinois.** Has 110 miles of 2 through 12-in. for *South Georgia Natural Gas Company*.

● **Associated Pipe Line Contractors, Box 13216, Houston, Texas.** Has 63.5 miles of 36-in in Louisiana and Mississippi and 71 miles of 30-in. in Virginia and Maryland for *Transcontinental Gas Pipe Line Corporation*.



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How To

SCHEDULE ENGINEERING

To Meet Critical Dates

W. G. Snyder

IN a very real sense, successful engineering scheduling—the term engineering being used to define general engineering and related design work—is comparable to a well-played chess game. It calls for the skillful maneuvering of total manpower through a sequence of interrelated preliminary objectives to an ultimate goal, under timing, and with regard for the total estimated number of man-hours required for, and those actually applied to, each objective as well as the relative position of each man at any given moment and his individual "weight."

Engineering scheduling is a problem of major importance. Failure to meet established critical dates for the completion and delivery of specifications and drawings covering each of the several phases of a total project can result in substantial dollar losses to the plant owner. These losses may be expressed in such terms as excess rental charges for heavy construction equipment, premium construction labor rates, premium costs for the fabrication of structural material and processing equipment as well as for the manufacture of mechanical equipment, increased expediting costs and shipping charges, and finally loss of revenue from the process plant due to late start-up.

EXCLUSIVE

To meet this problem, engineering departments and engineering concerns have contrived various kinds of scheduling devices ranging from the familiar tag boards to equipment representing an investment well into five figures.

The Author

William G. (Bill) Snyder joined James P. O'Donnell, Engineers, in 1946 as head of the piping design department and is now chief draftsman. A high percentage of the organization's activities are concerned with the petroleum and chemical process industries, and Snyder's scheduling and general supervision of the design departments covers all operations in both the New York and Beaumont, Texas. offices.

Previously Snyder worked for Alco Products, Air-Trol Engineering, and the M. W. Kellogg Company. With the latter firm he was a group leader and piping design representative in the field with considerable experience on fluid catalytic cracking units and their recovery systems.

Snyder completed his formal education at New York University.

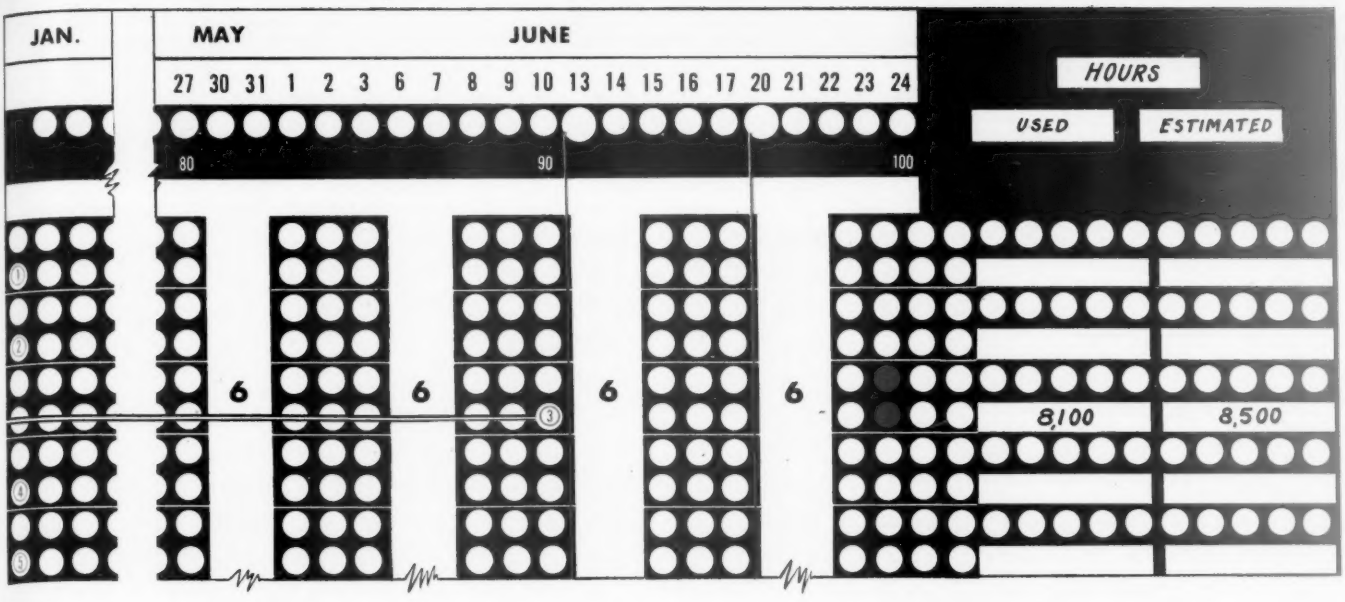


FIG. 1. Detail of the Estimated Manpower, Scheduling, and Job Progress Section showing two horizontal rows of peg holes assigned to each phase of a job. Scheduling data are shown for Phase 3. Reading shows the phase is 90% complete as of the current work week identified by the vertical red strings. Six men are shown working on the phase, and that number will be required to meet the phase critical date marked by the two red pegs posted one above the other.

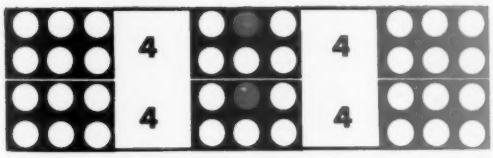


FIG. 2. Detail showing how manpower overages and shortages are indicated.

This article describes a relatively inexpensive, comparatively simple peg-type board and its *modus operandi*. It has proved very effective in giving a comprehensive daily picture of the progress and status of jobs, the allocation and utilization of manpower, and the entire operations against a wide range of critical dates.

The board functions to project engineering work across a maximum period of six months on a weekly basis, showing at all times the essential scheduling facts on as many as 20 jobs. It shows the total estimated number of man-hours required to complete each job, the number of men required to complete the drawings for each of its phases, e.g., civil, mechanical, electrical, and instrumentation, the number of man-hours actually used as of the current week, and the percentage of completion of each phase to alert us to our position in respect to all critical dates shown on the board.

Against the background of this visual information, the board enables us to control the deployment and utilization of a technical staff of 141 men in the New York and Beaumont offices, as well as men in the field, over the jobs in progress. Each of these men is identified on the board as to his office or field location, his classification or "weight," the job he currently is assigned to, and his supervisor. His absence from the job due to vacation or illness is also shown.

The data so presented permits keeping the overall operations in balance. It instantly reveals over or understaffing, and strong or weak scheduling spots. Similarly, it permits us to effectively control and restrain the aggressive job engineers who in every engineering office call for and otherwise usually get, a disproportionate number of men assigned to them. Against shown progress data, it enables us to estimate the availabiltiy of manpower for reassignment.

It is not unusual for the plant owner to call for job progress reports, and in proportion to the scope of the information, the size of the job, and the detail requested, considerable time is required to prepare these. Recently, the assistant chief engineer of a prominent oil company called for such a report concerning a major process unit. By referring to the board we were able to assemble information in a matter of minutes that otherwise would have required several days to obtain.

The board will be recognized as an adaptation of the peg-type widely used by manufacturers to schedule production through their shops. Its adaptation to our use was made by James P. O'Donnell, P.E., head of our organization, from the standard board manufactured by Wassell Organization, Inc.

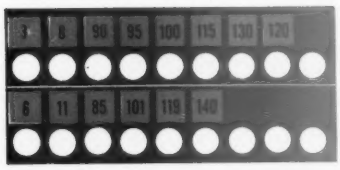


FIG. 3. Detail of the Applied Manpower Section.

For the purpose of description, the board has four sections:

(1) A personnel section,

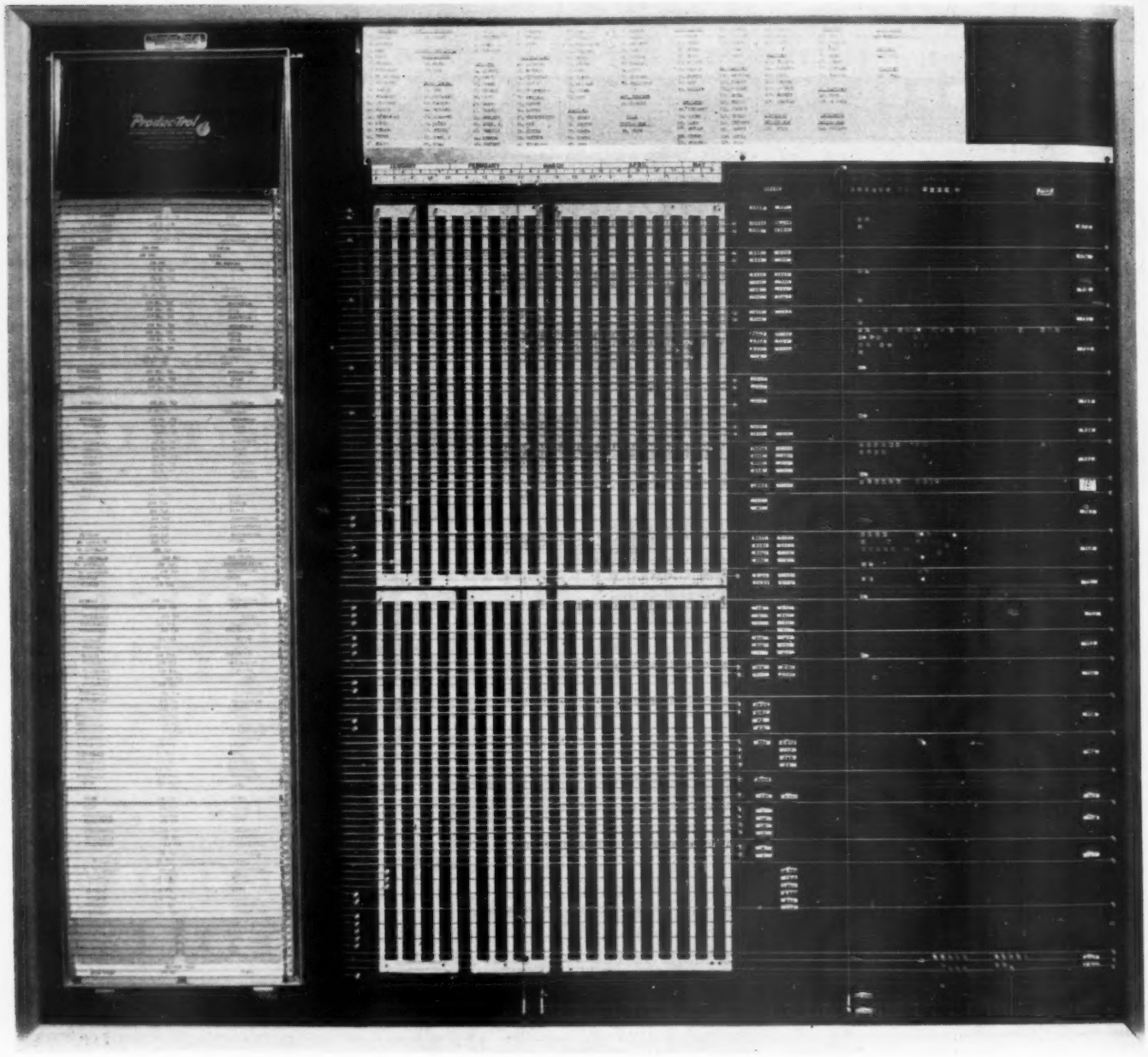
(2) A vertical job record card file section,

(3) An estimated manpower, scheduling, and job progress section, and

(4) An applied manpower section.

The Personnel Section

The Personnel section extends across the top of the board. It functions to list the names of all technical personnel, and to provide a cross-reference to the applied manpower section where small blue and red pegs are used to identify each man, the job and the phase of it to which he is assigned, and his "weight" or classification. This cross-reference is accomplished by assigning a number to each man corresponding to a number imprinted on



Engineering Scheduling Board showing Personnel Listing Section at top, Vertical Job Record Card File Section at left, Estimated Manpower, Scheduling and Job Progress Section in center, Applied Manpower Section at right. Broad vertical strips beneath date strip are removable plastic strip cards. Round, numbered pegs used show per cent of phase completion are attached to retractable strings. Pegs posted at extreme right show engineering of that phase is complete. These strings provide easy reference to other phases of the job.

the head of the peg identifying him. The listings also show whether the man is located in New York or Beaumont, or in the field and, if so, where.

Vertical Job Record Card File

The vertical job record card file section, at the left of board, contains holders for 100 job record cards. The purpose of this section is to provide a continuous, detailed, written record of each job, in each of its separate phases, from start to finish. It also provides a cross-reference to the round, white, numbered pegs used in the estimated manpower, scheduling, and job progress section to show the progress of each phase of the job, percentage-wise, in relation to its critical dates.

At the start of each job, the total engineering is broken down into five phases:

(1) General engineering—including supervisory engineering, engineering calculations, equipment analysis and selection, and specifications;

(2) Civil — including foundation, structural, and architectural design, and drafting;

(3) Mechanical—including vessel, piping, conveyor, and related design, and drafting;

(4) Electrical—including power and lighting;

(5) Instrumentation—including graphic and conventional panel boards. Since each phase will have its own critical dates, a separate record card is assigned to it; thus, each job has five such cards in this section. Certain jobs, of course, may have a lesser number of phases and the board can be easily adjusted to meet such situations.

All facts pertinent to each phase of a job are entered on the proper record card. These will include such information as the critical dates, changes in the scope of the job as requested by

the client and their extent, and notations of delays, if any, and the reasons for them. At the bottom of each card, the overall job number, job title, phase title, name of the client, and the name of the job engineer is typed for visibility through the plastic base of the card holder. To establish the cross-reference to the estimated manpower, scheduling, and job progress section, the card holders are numbered from 1 to 100.

Estimated Manpower Section

Fig. 1 illustrates the estimated manpower, scheduling, and job progress section which, on the board, is to the right of the job record file. The functions of this section are to visually show the critical dates for each phase of the job, the estimated number of man-hours required to complete it, the total number of man-hours actually used to date on a current week basis, the per cent completion of each phase, and the estimated number of men required against the number actually working on that phase as well as any man-power overages or shortages.

The components of this section include a portion of its face drilled to accommodate pegs; a date strip covering a six month period day-by-day; a percentage scale in tenths; removable, plastic strip cards positioned over the drilled portion to partition it by weeks; and vertical strings to mark the current work week.

The information in this section is visual and always read in terms of the current work week identified by the position of the vertical strings. One string is positioned to mark the week's start, and the other its close, their separation spanning six work days—Monday through Saturday. Each string is attached, top and bottom, to a peg so that it can be repositioned weekly.

This section is read vertically and horizontally. Vertically, the peg holes correspond to the dates on the date strip, and they also relate to the percentage scale. Horizontally, the peg holes relate to the individual job phases. For the reason stated later, two horizontal rows are assigned to each job phase and, except in cases where there are fewer than five phases, an extra job will occupy ten rows. The critical date for each phase is marked by a double red peg.

Small, round, white pegs, numbered one to 100, complete the cross-reference with the like numbered card file holders. These pegs are used to show the percentage of phase completion as of the current week. Peg No. 33, for example, would refer to file card No. 33—"Job 2211, Civil Engineering, Catalytic Reforming Unit, XYZ Oil Company, John Jones, Job Engineer." If positioned under "60," this peg would indicate that civil engineering on that job is 60 per cent complete.

The removable, plastic strip cards are positioned by weeks across the entire section. These are used to show the estimated number of men required for the extent of each phase of the job vs the number actually engaged on it for the current week.

A figure representing the estimated manpower requirement for the extent of a phase is pencilled in on the face of the strip card. Assuming that the estimated manpower requirement for the duration of a phase is six men, the figure "6" would be written on the strip card. If no pegs are posted in the holes to the right of this figure, the reading is that the six men estimated as required are engaged on that phase.

Manpower Overages and Shortages Shown

Fig. 2 shows that three holes per row appear between each strip card. As previously mentioned, two horizontal rows of holes are assigned to each phase. In adapting the board, this was done to make six holes available so that any manpower overages or shortages that might occur during the run of a phase can be shown.

Each of the six holes represents one man over, or under, the estimated

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number of men required as marked on the strip card. Manpower overages are indicated in these holes by blue pegs; shortages by red pegs. Thus, if the number pencilled on the strip card is "4", and a blue peg is posted in the second hole, top phase row, six men—an overage of two—are shown engaged on that phase. Conversely, a red peg posted in that hole signals that only 2 men—a shortage of two—are working on it. Circumstances will arise to produce manpower overages and shortages, and these signals enable manpower to be effectively concentrated where it is most needed at a particular time.

It is important that an engineering firm be able to estimate the availability of manpower for reassignment to future jobs. The strip cards permit making such estimates quickly and accurately by vertically totaling all scheduled manpower as shown on the strip cards, and subtracting that number from the total manpower.

Outside of the scheduling portion of this section, under the general heading "Hours", and in line with the row of holes related to a job phase, two rectangular white pegs are positioned side by side. The estimated number of man-hours required to complete that phase are marked on the head of the right-hand peg while the total number of man-hours actually used up to the current week are pencilled on the head of the left-hand peg. A simple ratio of these figures shows the percentage of hours used. This can be readily compared with the percentage of phase completion as shown by the position of the phase pegs relative to the zero to 100 per cent completion scale. The condition of a phase—"healthy" or "sick"—is immediately made evident.

Revisions in estimated man-hours, due to changes in the scope of the job, are immediately made on the respective pegs, and these are marked with an asterisk to provide a cross-reference to the detailed information noted on the job record cards.

The Applied Manpower Section

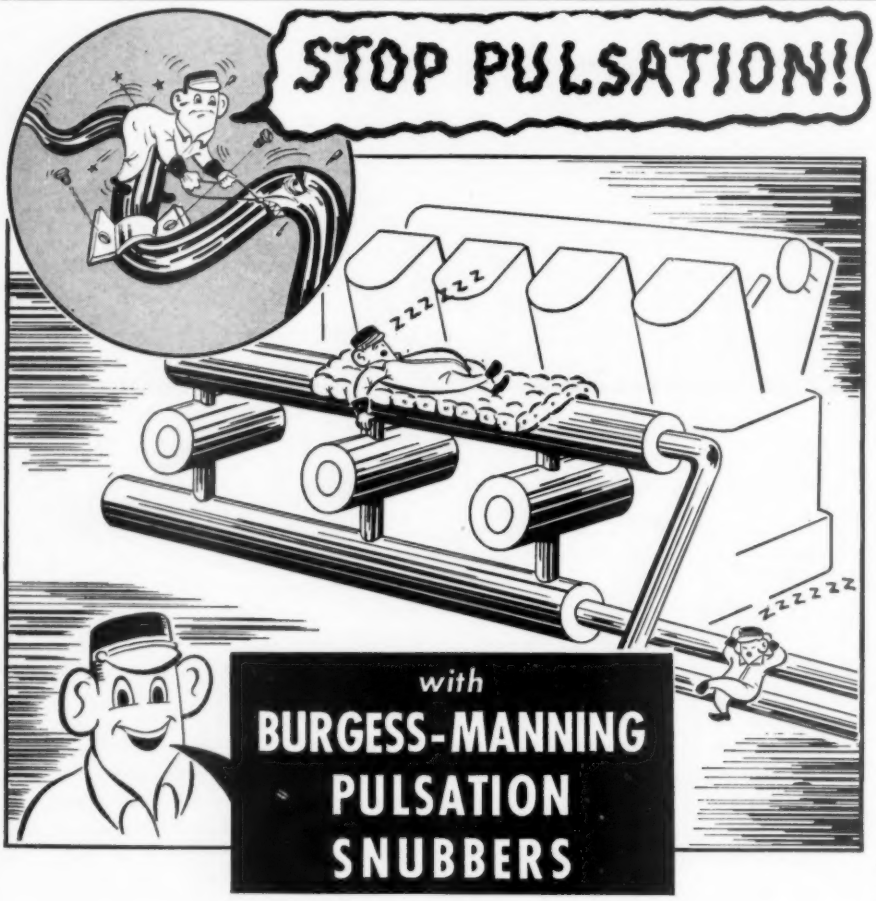
For payroll purposes, our technical staff is divided into six classifications: (1) Engineers, (2) section heads, (3) group leaders, (4) designers, (5) senior draftsmen, and (6) draftsmen. For scheduling purposes, these are reduced to two classifications—"heavy" and "light"—so termed for convenience and because the men in classifications 1 to 4 usually direct those in 5 and 6.

The information in the applied manpower section (Fig. 3) is read horizontally from the rows of peg-holes which extend across it from the estimated manpower and scheduling section. Each man on the technical staff is represented in the applied manpower section and identified by a numbered blue or red peg. Blue pegs are used to indicate "heavy" personnel, red pegs to identify "light" personnel, and the number on the head of each peg refers to the number opposite that man's name in the personnel section.

As each man is assigned to a phase of a job, his peg is posted in the row related to it. When a man is on vacation, ill, or otherwise absent for a period of time, his peg is removed from the phase row and placed at the bottom of the board next to a rectangular white peg headed "Vacations."

A glance at this section shows the distribution of total manpower, its distribution per job and per phase, and the allocation of "heavy" and "light" personnel to enable us to keep our operation in balance in all of its aspects.

Normally, we set the board for a six-month period. About midway through it, the board is re-set so that, at all times, at least three months of future work is shown. The removable strip cards make the re-setting process comparatively simple since the last three months of scheduled work, already shown on the strip cards, moves over and automatically becomes the first three months of work on the re-set board. * * *



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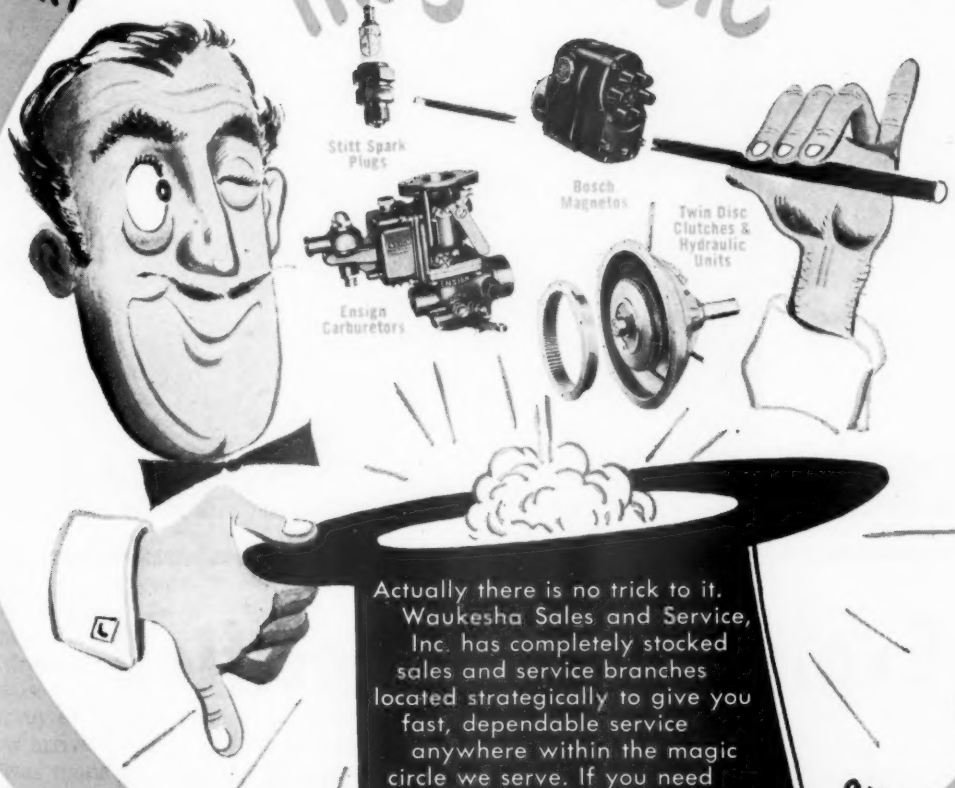

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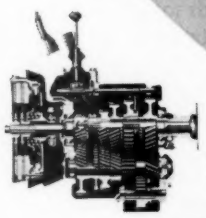
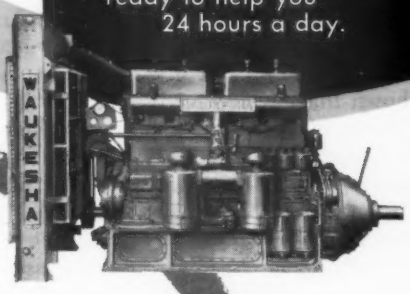
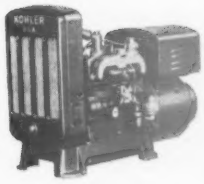


Spicer Transmissions and Parts





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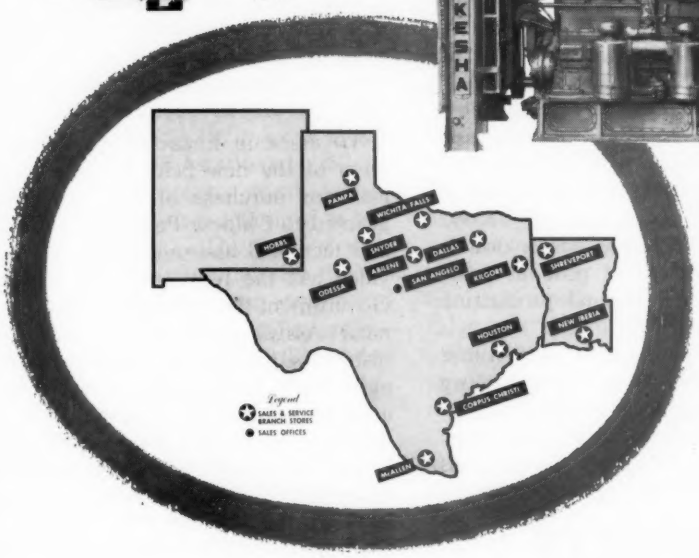

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Extension well EB-10 at Chutauchi South Culmination field showing rugged terrain of this mountain-top field

P 149.

Exploration Intensified in Taiwan, Formosa

Leo W. Stach*

HIGHLIGHT of operations by the government-owned Chinese Petroleum Corporation in 1954 was the discovery of commercial production of high grade crude oil and gas by the wildcat well Chutauchi EB-8 on January 18, 1954, at the small south culmination of the large Chutauchi structure in the foothills of southern Taiwan.

Although small quantities of crude have been produced both at Chinsui gas field and from the south plunge of the Chutauchi structure, this discovery can be regarded as the second commercial productive oil field to be found in Taiwan, half a century after exploitation began at the old Chuhuangkeng (Shukkoko) field in 1904.

Subsequent extension drilling has shown that the productive area of the Chutauchi South Culmination field will be quite small, but the two more productive zones below that found by the discovery well were tested and proved during 1954. Production of 14,828 bbl of crude from the discovery well, and from one extension well completed in August, accounted for 42 per cent of Taiwan's total production of 35,082 bbl in 1954, which was nearly double that of the average of postwar years and is the highest annual production achieved since 1940.

This discovery, together with other small successes of Chuhuangkeng where an extension well and a deepening both found some small production of crude—and at Chinsui (Kinsui) —where one of two extension wells found production of 210,000 cu ft of gas daily—added further impetus to exploration activities which were revived with the encouragement of the U. S. Foreign Operations Administration in 1952.

To assist in financing the development of the new field at Chutauchi a loan for purchase of equipment was granted to Chinese Petroleum by FOA and technical assistance was also provided. At the request of the Chinese Government the United Nations Technical Assistance Administration furnished the services of a petroleum geologist from May, 1954, to advise and assist with the exploration and development program, and a micropaleontologist arrived in November to introduce systematic biostratigraphic research and train local staff.

Interest was also revived in the po-

*United Nations Expert in Petroleum Geology to the Government of China (Opinions expressed do not necessarily reflect those of the United Nations).

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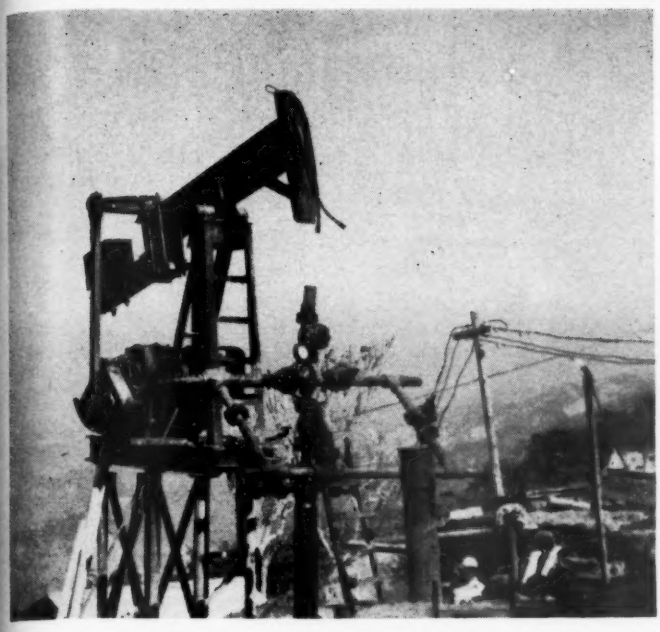
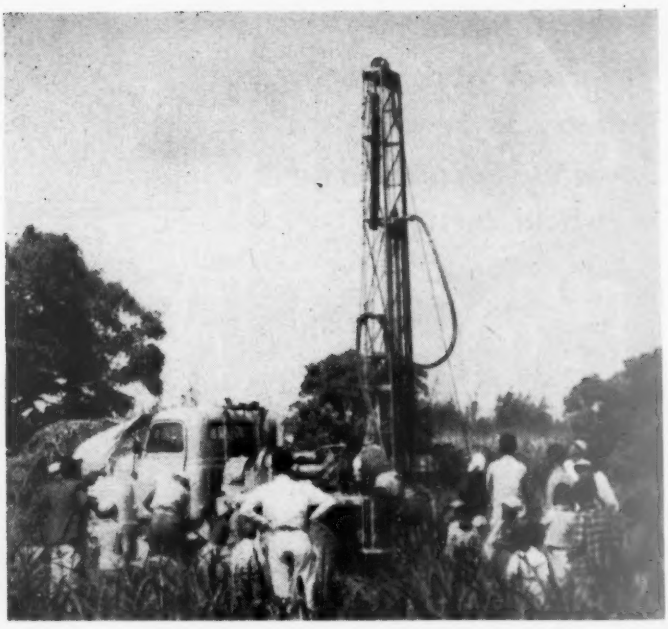


Discovery well of Chutauchi South Culmination field, formerly pumping from zone 3, now flowing from zone 5



Chinese crew operating new Failing shothole rig during seismic survey for Chinese Petroleum Corporation in cane fields of Formosa

tentialities of the western coastal plain where activity declined in 1949 after abandoning two wildcats drilled on conspicuous anomalies indicated by regional and detailed gravity surveys of the entire western coastal plain conducted by Chinese Petroleum in 1946-47. Structure drilling began early in 1954 in the plain near Chiayi (Kagi) and seismic survey equipment ordered early in the year arrived in October.

A contract was made in December for the services of a seismic crew from the Teikoku Oil Company of Tokyo, Japan, and shooting for the first seismic survey ever to be undertaken in Taiwan started early in January. The purpose was to detail a structure proved to exist by one of the wildcats drilled on gravity data. Later reconnaissance profiles will be run in other areas where structures are suspected to exist beneath the superficial deposits of the western coastal plain.

During 1954 the results of new geological surveys made in the western foothills zone since 1952 were evaluated and test well locations were selected for several promising prospects, at least four of which are planned to be drilled during 1955. The first of the series, to test the potentialities of the lowest part of the Miocene section in the Shantzechiao structure a few miles southwest of Taipei, began drilling late in December. A rig is also now being moved to a site to test for production on the culmination of the underthrust west flank of the Chutauchi structure, from the same zones found productive in the south culmination.

Additional detailed geological surveys will be undertaken during 1955 particularly in southern Taiwan where attention will be concentrated on the central and northern regions of the large Chutauchi structure, which is more than 30 kilometers long, to locate the exact position of large culminations already shown to exist in the eastern overthrust block of this axially faulted structure. The south culmination, tested first because of its relative ease of access, is a minor structural high on the south plunge with a closure of only about 250 meters northward, beyond which the structure rises perhaps another 1000 meters before closing to the north. Producing zones of the south culmination are exposed in the central part of the structure so that potential targets will be in Miocene rocks, which are not known to outcrop in this general area.

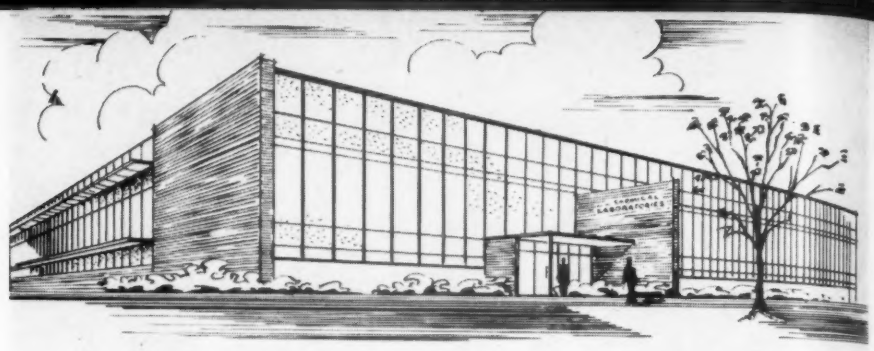
The culmination in the central part of the structure lies in even more rugged terrain than that of the south culmination, among sharp ridges rising abruptly about 2000 ft above the valley floor and several kilometers from the nearest motor road, so that cable haulage on inclined rail tracks will be needed to gain access for drilling. This is also the case at the south culmination field where the main incline to the ridge crest rises more than 1000 ft over an average 40 deg slope, and 8 more smaller inclines along the ridge crest are required to reach the present wells.

Following up on reconnaissance surveys made in 1954 of the large Sanchienshan structure, which lies across the syncline to the west of Chutauchi and is very similar to it in both size and structure, detailed surveys will be made in 1955 on selected areas. Detailed surveys are now also in progress on the Pakuali structure which lies to the north and east *en echelon* to the Chuhuangkeng faulted anticline, on which the old field is situated, to enable selection of a location for a test well, which should begin drilling in the latter part of 1955. Reconnaissance surveys in 1954, aided by photogeological interpretation, indicate a very similar structure to that of Chuhuangkeng and, since Pakuali is exposed to about the same stratigraphic level as Chuhuangkeng, production may be found in the same zones as that field.

With the additional production that should be obtained from further development of the Chutauchi South Culmination field during 1955 a new postwar record for crude production can be expected, without taking into consideration additional production that may be obtained from the wildcat program already underway for 1955. Production of natural gas, which has long been more important economically than the crude production in Taiwan, showed a decline in 1954 to 1,025,968 Mcf which was only 94 per cent of the 1953 production, in spite of 61,725 Mcf contributed by new wells completed in 1954.

The significant, though small, discovery at the Chutauchi south culmination, considering its geological setting, has greatly enhanced the prospects of finding considerably larger deposits and has stimulated exploration in Taiwan on a broader basis and at a larger scale than at any time since the war.* * *

Scientists and engineers work with industry to keep up with the present and hold a . . .



Phillips new multi-million dollar chemical research laboratory

P 932.395

PERISCOPE on the FUTURE

Ernestine Adams*

IT'S the fastest growing part of the petroleum industry. It's the big wheel that hurries progress.

It's a small word but the largest factor in growth and prosperity!

It's research!

In the three years, 1952-54, the funds devoted to petroleum research doubled and this year expenditures will go even higher. Cost of research in 1954 ran to some $211,000,000, more than twice what was estimated by the API in 1952. This amount covered only salaries, supplies, and maintenance. It does not include capital investment in research plants — new buildings are going up in numbers and present laboratories are being expanded. There is a growing demand also for scientific equipment; electronic computers, and mass spectrometers, which cast light through layers of data, are objectives of researchers' shopping.

Scientists and engineers and technicians are being sought—schools are beginning to give specialized training for research work. Discussions and seminars are held to promote creative thinking and creative ability.

New research divisions are being organized in companies which have had none before; in some, subsidiaries are established for the sole purpose of investigating and developing company projects and products.

University research is being supported by the industry and research service centers are being retained by companies individually and in groups to handle specific projects.

All these movements indicate the respect research holds in the petroleum industry today and the acceptance of its vital need by industry.

*Management Editor.

Utilization of research findings was widespread in oil industry from early days. It took considerable investigation to develop a kerosine that burned readily and cleanly yet did not explode.

But never has the value of research been so significant as in the last few years, and this increasing importance is felt in both its phases—research into industry operations and investigation of new and improved products for the market.

Studies of more efficient operations have provided the industry with better equipment and better methods in exploration, drilling, producing, processing, transporting, storage, and marketing. In some more detailed accounts that follow are specific improvements, which mean greater oil and gas supplies more efficiently handled and consequent lower costs that benefit the consumer.

This type of research goes on constantly in individual concerns and in organizations of petroleum companies; often with the aid of equipment and service companies. The industry would have slowed and faltered long ago without the guiding hand of research. The multiplied oil recovery from old fields, fracturing methods, up-grading of refinery products, a new petrochemical industry—all these and many more vital operations have come through research.

Researching for new products means that developments in other fields must be watched and followed. High grade gasolines must be ready for new car engines, tougher lubricants are needed for jet speed.

By-products of operations must be investigated and put to use. The sulfur extracted from sour gas is a worthwhile product made from what was once waste. A refinery by-product gas, which contains 50 to 90 per cent hydrogen, has been converted to a product useful in manufacture of ammonia.

Research has brought many new wonderful things to the market—detergents, nitrogen fertilizers, wax for coating paper, asphalt for roofs, and a hundred other products that make life easier and more pleasant for the consumer.

All refiners put their prime research work on two items—gasoline and lubricants. The past year has seen nearly every company put higher grade gasoline and an extended line of improved lubricants on the market. These have not been mentioned in the individual company reports because the stories are similar although each one of the products has distinguishing characteristics.

The money spent for research is only the beginning, of course. It is due primarily to research that capital expenditures run so high in the petroleum industry. New processes mean new plants and rapid advancement means rapid obsolescense. Competition, becoming keener for the consumers' dollar, has inspired the jump in research organization and expenditure.

Private research means greater competition, too, for each company endeavors to top the others in quality products and to put new items on the market. The oil industry spends more than any other on research—about 8 per cent of the $3 billion being spent by all industry.

The petroleum industry's research is not limited to oil and gas. When production of wartime penicillin was hampered by problems of separation be-

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cause impurities were getting through and quantities were limited, Shell's Research Center at Emeryville within four months perfected an extraction process which permitted manufacture of quantities of the new drug.*

Research is a concentration of the best knowledge and thinking bent on improving human welfare. Like many good movements, as it goes forward, it increases the length of its stride.

Here is what individual companies are doing in research:

ATLANTIC: Atlantic employs 550 persons in its Research and Development Division which is housed in the new production laboratory at Dallas, Texas, and in the main research center at Philadelphia. Cost of research runs about $5 million a year.

Some of the results of Atlantic research now in use are: Odorless solvent used in manufacture of paints, wax for coating paper milk containers, special greases and gear lubricants for steel mill use, ammonia for agriculture, synthetic detergents, asphalt products.

Catforming, developed by Atlantic, is licensed to other refiners.

Use of gas injected at very high pressure to increase recovery of petroleum from underground reservoirs was discovered by Atlantic engineers and is in use in West Texas.

The company has developed and applied electronic computers, mass spectrometers, and other modern tools and methods of modern science.

CARTER: Research Laboratory at Tulsa, Oklahoma, was expanded in 1954. The main laboratory was made a third larger; a new drilling research building and a warehouse were constructed.

Studies are devoted to new drilling methods and equipment; coring techniques; better ways of using well test data; use of magnetic tape to obtain and analyze seismic field data; migration of oil, etc.

CITIES SERVICE: Research and Development has brought several long-term development projects to a successful conclusion. A railroad diesel oil was placed on the market, as were new and improved automatic transmission and converter fluids.

Automotive and industrial greases were expanded by development of a multi-purpose lithium grease. Industrial lubricants were strengthened by new gas compressor oils, quenching oils and steel mill roll neck oils. A new line of rust preventive materials for both military and industrial purposes was put on the market.

In the field of oil production, investigation of processes of primary and secondary oil recovery led to developments which should increase recovery from oil reservoirs.

To supplement this research program, Cities Service contributes financial support in fundamental research to universities and research centers throughout the United States in diverse fields of science and technology.

*Shell News, May, 1955.

This "electronic brain," one of the largest in the country, is installed at Magnolia's big Field Research Laboratories, Dallas, Texas. O. D. Ferris, research physicist, is feeding facts into the instrument. These electronic computers have probably done more than any one piece of equipment to further petroleum research. Dr. D. H. Clewell, head of the Dallas laboratories, says that every problem solved widens the horizon and reveals several other problems.

COSDEN: Has research laboratory at Big Springs, Texas, where investigations, specially in petrochemicals, have been a prelude to commercial exploitation.

DOUGLAS OF CALIFORNIA: Research by Douglas is mostly in asphalts, a field where the company is one of the largest independent producers. The laboratory at Paramount, California, developed air oxidized asphalts, road oil emulsions, industrial emulsions, asphaltic cutbacks and asphalt compounds.

Many products have been developed and improved to meet specialized needs of highway and airport building programs, of automotive and construction industries, and for export to many parts of the world. Specialities now being produced by the company include automotive undercoater, sound deadener, pipe coating, refrigeration insulation, battery sealer, electrical cable weatherproofing, roofing and weatherproofing asphalts and various types of industrial emulsions.

New barges to handle asphalt are also innovations to meet requirements of greater efficiency. Specially constructed barges, an innovation on the Pacific Coast, will be used to transport bulk cargoes of asphalt. The first barge will have a capacity of more than 2500 tons and will be equipped with facilities for heating asphalt to liquid form to facilitate loading and discharge of cargo by pumps.

GULF: Construction of a new Automotive Products Laboratory is under way in the Research Center at Harmarville, Pennsylvania. At Gulf more than 1200 scientists, engineers, and others are engaged in research.

Important improvements have been made in seismograph equipment used in surveying the underground structure, and new equipment is being made for use by field parties.

The Research Center participated in development of a new drilling mud to reduce drilling costs in certain areas. Field tests of a new percussion rotary drill indicate that this tool will be useful in drilling hard formations and for straightening crooked holes. New instruments were developed for control of pipe line operations. A study of ocean wave forces is underway to provide information essential for the design of structures suitable for drilling and producing in deep water.

A hydrogen-treating process was developed for improving cracked and straight-run furnace oil distillates, and units are being designed for two of Gulf's refineries.

Petrochemical research centered on diversification of the Oxo process now in commercial operation. Radiation studies are developing methods in use in both field operations and laboratory research.

HONOLULU OIL: Industrial Research Division in this company is devoted to development of specialities in oil field

pumping equipment and to hard surfaced liners for the rubber and plastic industries. A recently developed process for making certain types of centrifugal castings is opening up a new field of activity, and other interesting and profitable developments are in prospect.

HUMBLE: Houston, Texas, Research Center was dedicated last September. It was built and equipped at a cost of about $3,800,000. Baytown, Texas, Research Center was opened by Humble in 1951.

Among the continuing projects are: Exploration instruments, techniques, and methods of analysis, particularly in geophysics; methods of completing wells; refining processes to produce aromatics and improve quality of gasoline and lubricating oils; new analytical techniques; and new procedures for utilizing electronic computers.

A seismic velocity logger is being used to measure the speed of sound in individual rock layers penetrated by wells. Resulting data make possible a more convenient and less expensive method of computation in geophysical work.

Better interpretation of electric logs of wells has resulted from development of reasonable explanations of some of the causes of the phenomena measured.

An improved procedure for determining the age of geologic formations, based on the measurement of Carbon 14, is now being used on a routine basis. It has a useful range from the present back about 35,000 years.

Past studies of factors affecting rate of drilling with drag bits are being extended by the use of an electronic computer to compare the relative merits of size of hole and drill pipe in 55 combinations of equipment of interest in current drilling operations. Modification of roller cutter bits used in soft Gulf Coastal formations resulted in 50 per cent longer life for the bit and slightly faster drilling.

LION OIL: Within the past year Lion has begun construction to enlarge its research laboratory space and has added new personnel to this division.

Lion is active in projects dealing with acetylene, acrylonitrile research and development, vinyl chloride, urea, polymer development, ammonia pulping and many organic agricultural chemicals. Emphasis is placed on products which can be developed from the raw materials, waste and by-products available to the company at its present operations.

Among results of the Research Division is improving Lion's petroleum and chemical products, and the processes by which they are manufactured.

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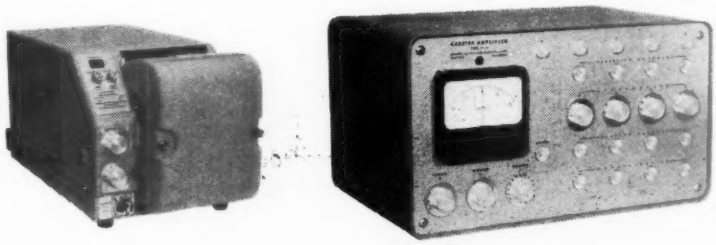

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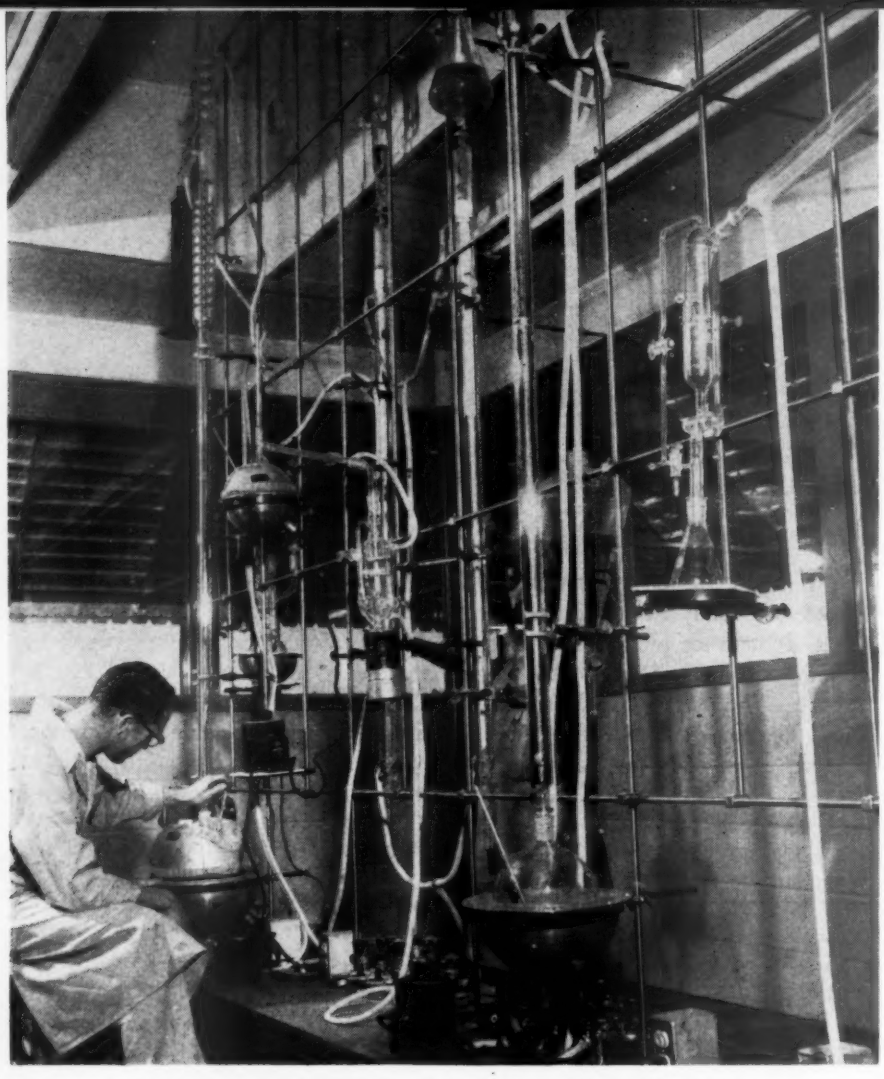

Test tubes at Cosden research laboratory, Big Spring, Texas.

OHIO OIL: A number of well qualified scientists were obtained as the nucleus of the staff of the Research Department which was established January 1, 1954, by this company. The Denver, Colorado, area has been selected as the location of the laboratory. Completion of the laboratory is scheduled for the spring of 1956.

PHILLIPS: A new multi-million dollar Chemical Research Center Laboratory will be built west of Bartlesville, Oklahoma, at Phillips' Research Center.

During the past 10 years Phillips research has produced such outstanding petrochemical developments as oil furnace carbon black, improved synthetic rubber and, most recently, a type of polyethylene plastic, trademarked Marlex, to be produced in a large new plant just announced for construction near Houston, Texas.

Specialized irradiation services of the Materials Testing Reactor west of Idaho Falls, Idaho, which Phillips operates under contract for the Atomic Energy Commission, were made available in 1954 to private research and industry for commercial experiments.

The company has developed a new combination of drilling fluid ingredients to increase drilling speed and save drilling bits; also well-logging procedures, a meter for measuring flow of liquids in wells, and new methods for seismograph computations. A low-density oil well cement was formulated for better control of well-cementing.

Phillips increased use of electronic computers to gain more effective utilization of engineerng and scientific manpower and to make substantial dollar savings.

SHELL: A new building for the Radiation Laboratory at Houston, Texas, was constructed in 1954 and a new Radiation Laboratory is being built at Emeryville, California. The Houston building has a multi-million volt Van de Graaff particle accelerator.

Exploration and Production Research will have a new building soon at Houston and the Emeryville Research Center is being enlarged and remodeled to provide 50 per cent increase in space.

A second electronic digital computer and an analog computer have been added to the Numerics Laboratory.

The Agricultural Research Division, with laboratories at Denver, Colorado, and Modesto, California, has a basic program of synthesizing and studying new chemicals for pest control. A number of new materials with potentially useful properties as insecticides, fungacides, herbicides and soil fumigants have been found.

Among studies at the Houston laboratory are fundamental investigations of the flow of fluids in reservoir rocks and of well productivity.

At Emeryville engine fuel and lubricant requirement are under investigation. One new cracking catalyst was put into commercial use last year.

SINCLAIR: A new platinum catalyst has been developed in Sinclair's Harvey, Illinois, laboratories in association with Baker and Company, Inc. Atomic energy research was used in developing the catalyst.

Sinclair production research scientists continued field test of the company's patented underground heatwave process for releasing crude oil not recoverable with conventional production methods. Data collected indicated that more extensive operations on a semi-commercial scale should be undertaken to develop the process further. A site for these operations is now being selected. Field trials also continued on Sinclair-owned lands in Colorado to apply underground heat to the recovery of shale oil.

Radioactivity measuring devices are being used to analyze core samples taken from wells, providing yet another tool for studying formations.

SKELLY: A central laboratory is maintained at Pawhuska, Oklahoma, where continuous research is conducted to increase manufacturing efficiency and develop products and processes.

SOCONY MOBIL: Research here developed methods by which the company's Thermofor Catalytic Cracking (TCC) process can convert substantially larger amounts of heavy residual fuel-oil components into gasoline and other higher grade products.

Socony scientists are pioneering in the application of modern, high-speed computing methods to research in producing and refining. They are using electronic digital computers in working out better ways of increasing recovery of crude oil and natural gas from underground reservoirs in Magnolia's Field Research Laboratories in Dallas and in determining more efficient refinery operating conditions in the Socony Paulsboro, New Jersey, laboratories.

Socony laboratories have been doing important work for several years in nuclear physics, especially as applied to exploration and production operations.

In 1954 Socony spent $16 million on research alone.

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SOUTH PENN: Research continues to be an item of great importance to this company with work progressing not only in its own Eastern and West Coast laboratories, but also cooperatively in those of others, some through research grants. The scope of this research activity ranges from the techniques of increasing the ultimate yield of crude oil from the presently operated producing reservoirs to the development and manufacture of new and higher specification products.

SUN: Ground was broken for a new laboratory for research and operational services near Dallas. The research program in geology presently being conducted at several locations in Texas and Louisiana will be consolidated and broadened at the new center.

A laboratory for the Research and Development Department was completed last year at Marcus Hook. Construction of a similar building at the same location has begun.

A special research unit was established in 1954 to study the application of advanced techniques of seismic exploration. Apparatus improvements doubled Sun's ability to process magnetically recorded seismic records.

A new high speed electronic reservoir analyzer was completed and placed in operation during the year.

New motor oil under development for four years has been placed on the market as well as eight new waxes, four new soluble oils and an automatic transmission fluid. A process to improve naphthenic lubricating oil was put into operation last October.

An important activity of Sun's Research and Development is conducting market and economic studies for new plants, products, and other important manufacturing changes.

STANDARD OF CALIFORNIA: The research branch at La Habra, in southern California, has devoted most of its time to the study of new techniques for finding oil, for drilling and for conservation.

Research frequently extends into unusual fields which may seem remote to the oil industry, but which are vital to its operations. As an example of such unique studies, California Research men worked with the two subsidiaries in the Gulf Coast of Louisiana and Texas to measure and record the forces of ocean waves. The information to be derived is expected to prove valuable in the design and construction of offshore drilling platforms.

Process research emphasizes development of a number of catalysts used in modern refining equipment. Improvements in this field permit the selection and design of new plants and more economic operation of existing plants.

In the chemical field a commercial process to produce the material isophthalic has been developed by Standard of California. Interest displayed in this material by the paint and plastics industries appears to assure its success.

STANDARD INDIANA: This company has put a special laboratory into operation at Seymour, Indiana, to work on solid propellants for rockets and guided missiles for the Air Force.

The Engineering Research Department has developed durable construction materials for use in refineries. Electronic analogues were used here to solve complex design and operational problems. Two quality-control instruments were invented and licensed for manufacture.

Standard Indiana's Ultraforming process for increasing the octane number of straight-run gasoline was put into operation last year.

Emphasis here is placed on the study of future automobile engines so the demands on fuels and lubricants for higher compression ratios can be met.

Stanolind has developed a series of inhibitors that give protection against pipe and vessel corrosion in oil fields and refineries. In 1954 Stanolind's widely licensed Hydrafrac method of fracturing underground formations to increase oil flow was used on some 35,000 wells.

STANDARD JERSEY: First company to build an Atomic Energy Oil Laboratory is Standard Oil Development, a subsidiary. The radiation laboratory is to be constructed in Linden, New Jersey. The purpose is to improve and transform petroleum products through use of atomic energy. Many other companies use radioactivity in research in regular laboratories.

STANDARD OHIO: Sohio's research has grown rapidly in the last three years. Studies of combustion technology for longer than that resulted in the new gasoline introduced last year.

A new multi-purpose agricultural grease was introduced in 1954.

Research into product profitability, market potential and manufacturing process led to Sohio's entrance into the petrochemical field. A $17 million plant is being built at Lima, Ohio.

TEXAS COMPANY: Three new buildings to be completed in the spring of 1956 are on The Texas Company's program of research expansion. Two of these will go up at Texaco's largest research center at Beacon, New York and one, an analytical and testing structure, at Port Arthur, Texas, refinery.

Last year Texaco established a separate Research and Technical Department to centralize, coordinate and intensify the company's research activities. Besides the centers above there is a Producing Laboratory at Bellaire, Texas. The company spent $14,000,000 last year on research.

Some products recently developed were an improved automatic transmission fluid; a new diesel engine lubricating oil for high-power-output railroad Diesels; a new aircraft engine oil; specialized fuels and lubricants for jet-powered aircraft; and a number of industrial lubricants.

The Texaco Partial Oxidation Process, licensed for making hydrogen for use in ammonia production, is operating under license in four plants and additional licensed plants are being completed.

A method was developed which uses radioactive material to determine the entry points in underground formations of fluids used in flooding to increase the effectiveness of secondary recovery operations in partially depleted oil fields. The first license for the use of this process has been granted to a large oil field organization.

UNION OF CALIFORNIA: In December, 1954, Union broke ground for four new buildings to go up at its Research Center at Brea, California. These buildings with their equipment will cost about one million dollars.

An oil well corrosion inhibitor has been developed which can cut crude oil-lifting costs. Results of testing the Unitherm electric bottom hole heater show that the application of underground heat in wells of the company's Cut Bank field in Montana produced over half a million barrels of oil which, without heat stimulation, could not have been obtained in the same period. Subsurface heating has also produced significant increases in production in several California fields.

A newly developed chemical treatment made possible the recovery of oil from refinery slops which heretofore had been considered waste. The process not only reclaims oil at low cost, but it also frees tanks formerly in slop service for other uses. Nearly 50,000 bbl of clean oil were recovered last year in the company's Los Angeles refinery alone.

The corrosion inhibitor, the Unitherm heater and the process to treat oil-water emulsions are being offered to the trade. During 1954 several Unifining units, permitting utilization of high sulfur, high nitrogen distillates derived from low-quality crude oils, were brought on stream by licensees and have been successfully operated. A number of additional units are under construction. ★

First Quarter Reports Show General Upward Trend

Three out of four oil companies that release quarterly reports showed an increase in gross income over 1954 in their first reports for 1955. Only two out or three, however, showed a net income higher than for the first quarter last year.

This difference in gross and net is due to two principal causes: First, greater exploratory and drilling expenditures; and second, larger depreciation allowances.

The search for oil is becoming more expensive and the cost is holding down net gains. New methods have worked wonders in operations but even greater feats must be accomplished to make drilling more economic. Deeper wells and offshore operations, seen more and more in the future, also contribute to cost increase.

Greater depreciation allowance, on the other hand, is good news. For long after World War II, petroleum companies were allowed depreciation that made ridiculously small contributions toward replacing facilities. Actually capital was taxed as income when it should have been set aside to replace worn equipment and plants. Although this increased depreciation allowance comes off income, the amounts are held by the companies for capital expenditures and the investment will show up in stockholders' equity.

INCOME OF PETROLEUM COMPANIES FOR FIRST QUARTER, 1955

Company	Gross income ($1000)	Per cent of 1954	Net income ($1000)	Per cent of 1954
Amerada	26,897	123	6,400	138
Anderson-Prichard	13,573	99	611	89
Argo Oil	2,854	115	1,169	101
Ashland	60,897	98	2,095	103
Atlantic Ref	143,405	109	9,821	89
Aztex Oil[3]	501	117	137	—
Barber Oil	—	—	14,223[10]	496[10]
Bishop Oil	468	105	69	162
Chicago Corp.	—	—	15,523[9]	—
Cities Service	188,926	107	14,074	107
Continental	129,910	104	12,142	105
Cosden Pet	12,486	110	837	110
Creole	—	—	75,900	123
Deep Rock	9,234	84	1,309[8]	834[8]
Douglas Oil	5,786	99	118	85
Gulf Oil Corp.	—	—	45,320	114
Hancock Oil	10,699	108	1,229	66
Honolulu Oil	8,655	115	3,202	123
Humble Oil	985,577	96	146,303	89
Houston Oil	9,658	114	2,072	117
Lion Oil	30,499	116	5,247	151
La. Land & Expl.	6,200	106	3,375	113
Maracaibo Oil	483	101	104	86
Midwest Oil	3,364	106	1,596	108
Ohio Oil	65,790	101	10,379	102
Pacific Western	—	—	1,234	55
Panhandle Oil	3,134	93	211	73
Phillips Pet.	212,256	107	22,110	115
Plymouth Oil	26,609	123	2,204	115
Pure Oil	120,800	129	9,429[4]	133
Quaker State	12,930	112	825	100
Richfield Oil	49,464	120	7,141	108
Seaboard Oil	10,617	110	1,689	116
Shamrock Oil	9,896	114	2,020	112
Shell Oil[1]	354,000	107	46,285	86
Signal Oil	3,496	129	2,643	83
Sinclair Oil	281,791	107	21,208	107
Skelly Oil	55,980	107	7,698	107
Socony Mobil	—	—	47,000	102
Southern Prod.	4,272	76	1,230	85
Standard Calif.	289,186	107	53,131	102
Standard (Indiana)	445,700	125	34,951	126
Standard (Jersey)	1,526,000	112	177,000	120
Standard (Ohio)	81,000	108	6,080[1]	136
Sunray Mid-Con.[5]	78,109	—	8,351	—
Superior Oil[6]	24,515	99	3,614[7]	57
Texas Co.	428,395	110	56,021	110
Texas Gulf Prod.	4,080	125	1,855	127
Texas Pacific C. & O.	5,985	109	2,023	98
Tide Water Assoc.	121,026	102	8,083	91
Toklan Oil	335	113	67	92
Union Oil of Calif.	81,799	92	7,107	84
Union Oil & Gas of La.	5,483	115	353	105
Universal Consol.	1,354	101	502	122
Warren Pet.	24,553	89	2,425	113
Wilcox Oil	1,971	107	471	178
Woodley Pet.	899	121	94	48[2]

[1] Includes $879,000 property sale.
[2] Reduction due to abandonments amounting to increase of $101,348 in cost of dry holes.
[3] Former subsidiary of Southern Union Gas Company.
[4] Includes $990,000 pipe line property sale.
[5] First quarter combined results prior to May 16 merger.
[6] Six months ending February 28.
[7] Decrease due to increase of $2,100,000 in intangible development expenditures resulting from more intensive drilling program.
[8] Increase due mostly to result of sale to Kerr-McGee and sale of General American stock, which is nonrecurring.
[9] Because of extreme changes, net income is not comparable to 1954.
[10] Net includes $14,160,571 from liquidation of American Republics Corp.

Oil Demand Up 7½ Per Cent

Oil demand in the first quarter of 1955 was up 7½ per cent over 1954 according to the Bureau of Mines report. Demand averaged 9,250,000 bbl a day of which domestic demand was 8,890,000 bbl a day, up 7.7 per cent and exports were 340,000 bbl a day, up 2.5 per cent. Largest increase was in February when domestic demand was 13.5 per cent higher and export demand 2.7 per cent higher.

Colder weather resulted in the large increase for heating oil. The increased demand was unexpectedly high as the Bureau estimate was a 6.3 per cent rise.

Creole Expansion

Creole Petroleum Corporation has another expansion program under way in Venezuela. About $120 million is estimated cost of capital expenditures, or $10 million more than in 1954.

Royal Dutch Shell Plant

Gross income in 1954 rose 9 per cent over 1953 for the Royal Dutch Shell group. Operating income was $5,180,000,000 in 1954 and net income $375,200,000, 3 per cent over 1953.

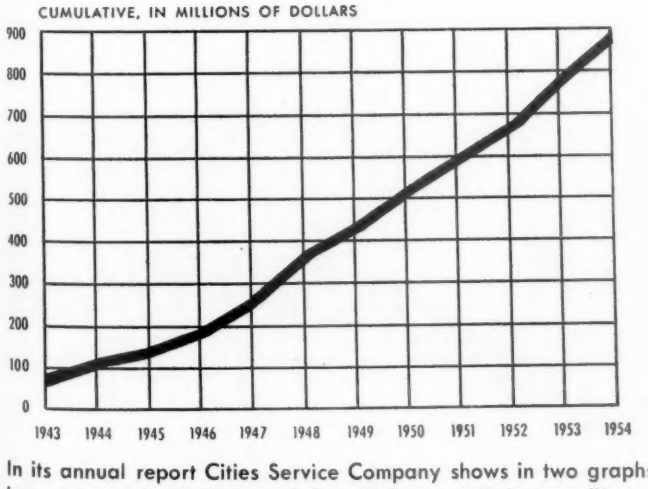
Capital expenditures totaled $632,800,000 last year and are expected to be more in 1955.

Socony Capital Expenditures

For 1954 Socony Mobil (Socony-Vacuum) capital expenditures were $265 million and estimates for 1955 are the same. The figure listed in the table on Page A-64, May issue for 1954, was in error.

CAPITAL EXPENDITURES

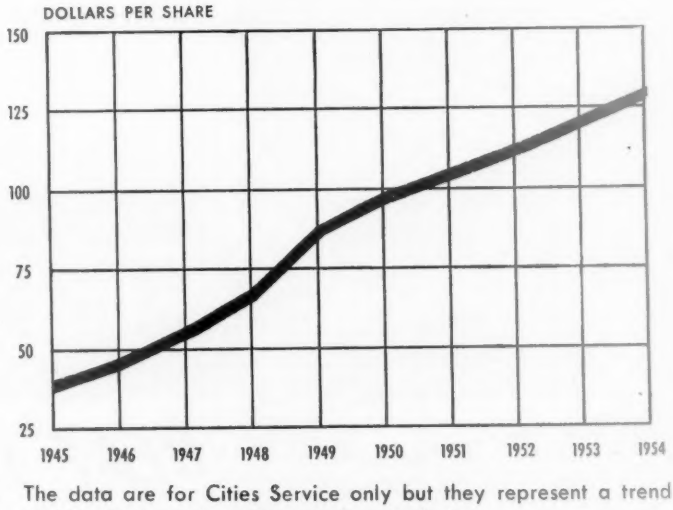
EXCLUDING EXPENDITURES BY UTILITY COMPANIES SOLD



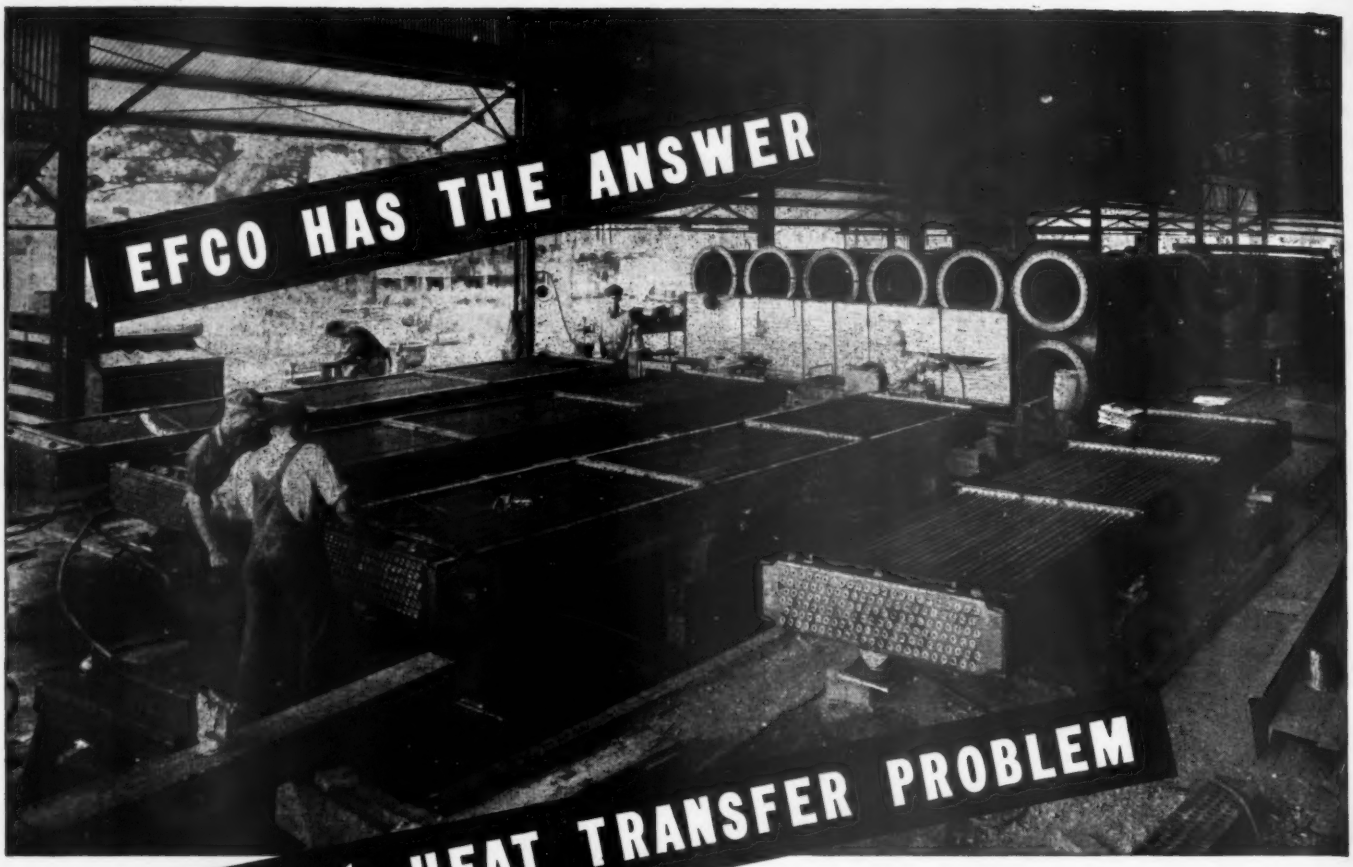
In its annual report Cities Service Company shows in two graphs how owners of common stock benefit from capital expenditures.

GROWTH OF COMMON STOCKHOLDERS' EQUITY

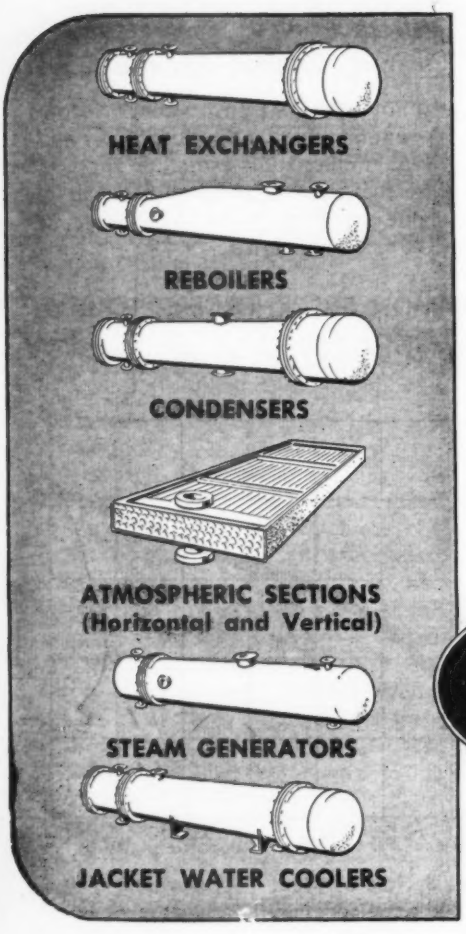
CONSOLIDATED BOOK VALUES BY YEARS AT DECEMBER 31



The data are for Cities Service only but they represent a trend that is felt throughout the petroleum industry.



If your problem is the poor performance or high maintenance cost of your heat transfer units, consult an EFCO engineer. He will help you decide the changes or modifications necessary to get the desired performance from your heat transfer equipment.
Backed by knowledge and experience, EFCO engineers are constantly working to produce heat transfer units that will give efficient performance and long, trouble-free operation.



ENGINEERS & FABRICATORS, INC.
P. O. Box 7395 Houston 8, Texas

EFCO
HEAT TRANSFER EQUIPMENT

THE OASIS

a spot for gathering Nomads

International guests at the April 13 regular monthly meeting of the Los Angeles Chapter of Nomads. Standing, C. R. Devine of D & E, Iran; D. S. Pitkeathly and Pat Docksey both of British Petroleum, England; G. W. Drenthen of Shell, Holland; D. H. Nations of Aramco, Saudi Arabia; C. A. Stoddard. Sitting, Jim Worsdall, Venezuela; C. C. Smart of D & E, Brazil; W. J. Chancellor of D & E, Iran; George Burke of Dunlap & Graham, Uruguay; H. M. Heath of Colombian Petroleum, Colombia; J. A. Wirtensohn of Asiatic Petroleum.

Nomads Meeting Dates and Secretaries

New York, Chapter, First Monday of the Month, Biltmore Hotel, New York. Secretary, Maurice F. Delano, Jr., R. S. Stokvis & Sons, Inc., 17 Battery Place, New York 4, N. Y.

Houston Chapter, Second Monday of the Month, Ye Olde College Inn, Houston, Texas. Secretary, H. Ben Young, Mission Manufacturing Company, P. O. Box 4209, Houston, Texas

Los Angeles Chapter, Second Wednesday of the Month, Jonathan Club, Los Angeles, California. Secretary, Earle R. Atkins, Emsco Manufacturing Company, P. O. Box 2098, Los Angeles 54, California

Tulsa Chapter, Third Friday, "After Five," Room, Hotel Tulsa. Secretary, O. B. Irizarry, *Petroleo Interamericano*, 211 South Cheyene, Tulsa, Oklahoma

Dallas-Fort Worth Chapter, Dallas, Texas. First or Second Monday of the Month. Secretary, H. A. Davis, H. A. Davis Power Equipment Company, 2142 Irving Boulevard, Dallas, Texas

Houston Nomads at their April meeting had the international visitors shown. J. H. Wilhelm of Socony Vacuum, Caracas, Venezuela; C. H. Jones of Sociedad Anonimo Petroleos, Las Mercedes; D. D. Dawson of Societa Petrozud P. E. Peazasa, Sollotto Pescori, Italy; W. C. Summy of Sinclair, Houston, Texas; Rex Hammaker, student; R. J. Young of Shell, Houston.

The club's annual bayshore party will be held at the Houston Yacht Club Friday, June 10, for Nomads and their wives. The fun begins at 6 p.m. with dinner, dancing, and games planned for the evening. The party will take the place of the regular June meeting.

Nomads at API

The Nomads annual luncheon to be held during the API convention in San Francisco will be on Monday, November 14, at the Sheraton-Palace Hotel.

Reservations should be made as soon as possible. Write Earle R. Atkins, Emsco Manufacturing, P. O. Box 2098, Los Angeles 54, California.

Visitors in May at the Houston Nomads were: Front row, John J. Foster of R. J. S. Germain, Houston; W. T. Short of Brazos Oil & Gas, Houston; J. G. Youngblood of Texas Petroleum, Bogota, Colombia; J. A. Wirtensohn of Asiatic Petroleum, Houston; E. F. Hulsman of Shell of Colombia, Bogota. Back row, M. L. Delano, export representative, New York; Del Redding of Phillips, Houston; R. L. Foster of Socony-Mobil, New York; R. E. (Bob) Smith, oil operator, Houston.

Guest speaker at the April 13 meeting of the Los Angeles Chapter of Nomads was Thomas Gearty, special agent of the FBI and assistant special agent in charge of the Los Angeles office. He is here shown with Joe Schlarb, chapter president, on his left and Bob Gaylord, sergeant-at-arms, and Rex Collins, deputy sergeant-at-arms, to his right.

New York visitors. Visitors at the New York Chapter of Nomads' meeting held in March included Guy Henley, Standard-Mobil Oil Company, Sumatra; Edward J. Coenen, Standard-Vacuum Oil Company, Sumatra; Robert C. Kelley, Dresser Industries, Inc., Dallas, Texas; Lawrence L. Rector, Rector Well Equipment Company, Fort Worth, Texas.

XUM

Front row, left to right—Courtney Berlin, Baker Oil Tools; Joe B. Woods, *The Petroleum Engineer;* L. L. Rector, Rector Well Equipment; Johnny O'Connor, Dresser Industries; Abbott Sparks, *The Petroleum Engineer.* Standing—Cliff Athey, Maxwell Steel; Ray Gorman, Web Wilson; Rollo Davidson, Bob Farson, both of Drilling Magazine; Gene Shiels, Ideco; Glen Tableman, W-K-M Manufacturing; Art Holloway, Lee C. Moore; Lewis Foster, Foster Cathead; George W. "Jack" Walton, Ideco; King Boyd, Stewart and Stevenson.

Johnny O'Connor Gives Fish Fry

J. B. "Johnny" O'Connor, popular executive vice president of Dresses Industries, Inc., recently was host at a fish fry to members of the Dallas-Fort Worth Chapter of Nomads. The affair, held at his picturesque Haderway Farm near Dallas, was pronounced a success from every point of view by the several hundred guests. The accompanying photographs picture a part of those present.

▲ T. L. Moody, Dresser Industries; A. M. Birnie, Security Engineering; H. R. Colter, Continental Oil; O. Hammer, Security Engineering; Lee Martin, Weatherford Oil Tool.

C. C. Book, Republic Natural Gas.

E. F. Shiels, Ideco; Fred Bradley, Southern Union Gas; John Guynes, Magnolia Petroleum; Dayt Clewell, Magnolia. ▶

▲ John Neale, Lane-Wells; R. M. Chan, Magnolia; John Lynch, LaGloria Corporation; G. Scott Hammonds.

▲ Gilbert Rowe, Rowan Drilling; C. Berlin, Baker Oil Tools; C. L. Rowan, Rowan Drilling; Jim Hughes, Lane-Wells.

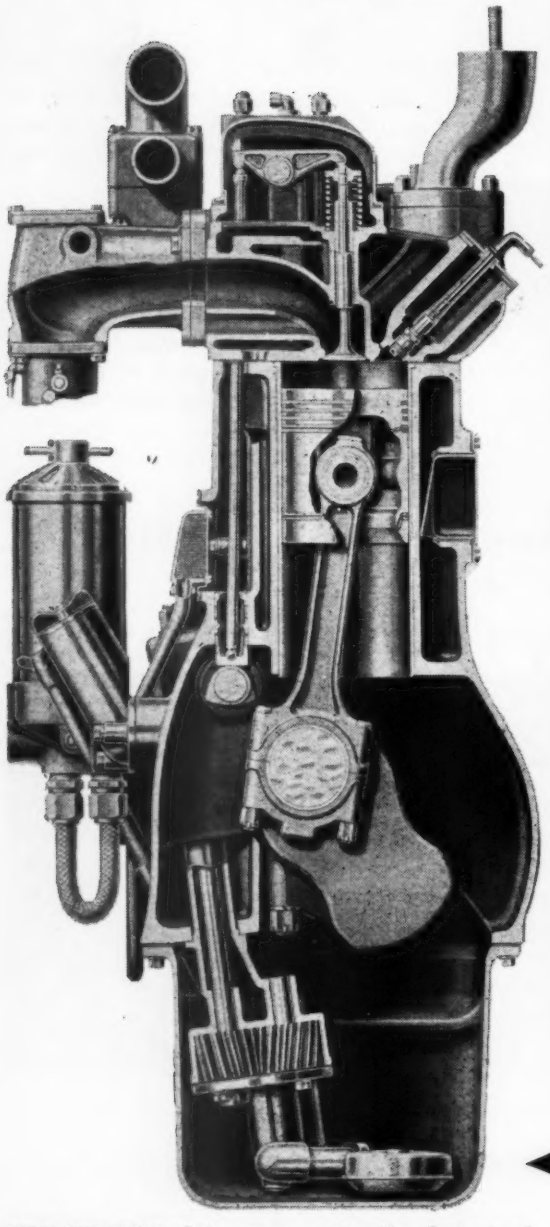
◀ G. Scott Hammonds; Wilbur Sherman, DeGolyer & MacNaughton; H. B. Hurley, Republic Natural Gas; Chet Wimberly, Halliburton.

John Evans, Stanolind; Bob Larboulette, Societe Cherifienne des Petroles (French Morocco); G. W. Walton, Ideco. ▶

Blondie Roberts, Reed Roller Bit; H. R. (Tex) Colter, Continental Oil; Chester Wimberly, Halliburton; Glen Tableman, W-K-M Manufacturing; Joe Kelly, Reed Roller Bit; Bill Behrehost, Ft. Worth Pipe & Supply; "Pop" Waldrop, Oil Base Rubber. ▼

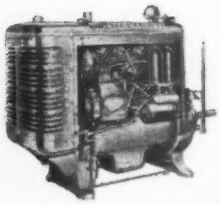
12 Solutions to Your Pumping Problems

Insist on INTERNATIONAL as original equipment on your pumps; they're tops for power as replacements, too!



HERE ARE SOME of the many outstanding features of this INTERNATIONAL U-1091 natural gas engine: seven-bearing counterbalanced crankshaft, torsional vibration damper, aluminum-alloy pistons, tin-plated for scuff resistance, replaceable cylinder sleeves, intake and exhaust manifolds on opposite sides for free flow of air and gas into engine and unrestricted outflow of exhaust gases, stellite inserts on exhaust valve seats, and full-pressure lubrication.

INTERNATIONAL 4-CYLINDER OIL FIELD ENGINES

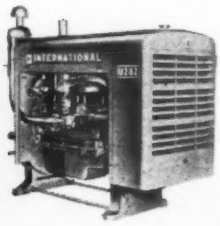


INTERNATIONAL U-264 engine is next to the largest in the 4-cylinder line with 264 cu. in. displacement and 29-52 horsepower range on the pumps.

SPECIFICATIONS

	DISP.	MAX. TORQUE @ RPM	RPM SPEED RANGE	HP RANGE
U-1	59.5	38@1700	1500-2500	8 to 16
U-2A	113	82@1200	1200-1800	15 to 24
U-164	164	124@1000	1000-1800	18 to 36
U-264	264	197@ 900	900-1600	29 to 52
U-9	334.5	229@ 950	900-1500	31 to 55

INTERNATIONAL 6-CYLINDER OIL FIELD ENGINES



INTERNATIONAL U-282 is one of seven new IH 6-cylinder oil field engines that have shown pumpers everywhere how to cut maintenance and operating costs.

SPECIFICATIONS

	DISP.	MAX. TORQUE @ RPM	RPM SPEED RANGE	HP RANGE
U-220	220.5	151@1200	1200-2400	30-62
U-240	240	166@1200	1200-2400	34-64
U-282	282.5	204@1225	1200-2400	41-75
U-372	372	263@1200	1200-2200	54-91
U-406	405.9	279@1200	1200-2200	56-98
U-450	450	324@1200	1200-2200	66-110
U-1091	1091.6	823@ 800	900-1600	136-200

An example of the sturdy construction of INTERNATIONAL *oil field engines is seen in the cutaway front sectional view of the new U-1091.*

The growing tendency to standardize on stand-out performers is adding to the reputation of INTERNATIONAL pumping engines throughout the oil fields.

The INTERNATIONAL line includes 12 models of 4-and-6-cylinder oil field engines, ranging from 38.5 to 823 lbs. ft. maximum torque—from 8 to 200 net horsepower.

If you need a full measure of honest power, IH is the line for the most exacting applications. Whether you need original equipment or replacement power, check with your INTERNATIONAL Industrial Power Unit Distributor or Dealer and discover how INTERNATIONALS can do your work better and for less money.

INTERNATIONAL® INDUSTRIAL POWER

MAKES EVERY LOAD A PAYLOAD

INTERNATIONAL HARVESTER

INTERNATIONAL HARVESTER COMPANY, CHICAGO 1, ILLINOIS

XUM

BTU Savings From Continuous Blowoff Heat Recovery*

Every boiler plant must take precautions to recover waste heat to reduce operating costs. The practice of blowing off even very small and low pressure boilers — as well as large, high pressure plants — intermittently and by hand is intolerable in these days of high fuel and labor costs.

In most cases, continuous blowoff heat recovery equipment, as installed, pays for itself in fuel savings in less than three years, and, in some cases, in less than two years.

For any given boiler plant, you can obtain in seconds the annual savings in millions of Btu per year resulting from the recovery of heat from boiler blowoff by means of a continuous blowoff system. Merely use this simple, four-step procedure as applied to the accompanying table and curves:

1. Determine the total dissolved solids in the makeup in ppm and choose the allowable concentration in the boiler in ppm from the following chart based on ABAI standards:

Maximum permissible TDS in boiler water

Boiler pressure, psig	Total dissolved solids, ppm
0- 300	3500
301- 450	3000
451- 600	2500
601- 750	2000
751- 900	1500
901-1000	1250
1001-1500	1000

Suggested limits sometimes recommended by experts for maximum permissible silica concentration in boiler water for various pressures are:

Boiler and turbine operating pressure, psig	Maximum silica in salines ppm as SiO_2
250- 600	40-50
601- 900	20-30
901-1200	10-20
less than 1200	less than 5-10 and less than 1 above 1800 PSIG

For high-pressure boilers, particularly where turbines are used with condensers for very low-pressure steam discharge, the maximum permissible silica concentration in the boiler water is usually set by the power engineer or consultant so that there will be no danger of turbine blade silica deposits.

*By V. J. Calise, Director, Research and Development, Graver Water Conditioning Co.

These values are subject to change based on operating experiences in the field and new experimental data.

2. From Table 1, find the per cent blowoff of the total evaporation. This table is based on 100 per cent makeup. If the makeup is less than 100 per cent, use this formula to calculate the blowoff in pounds per hour:

$$\text{Blowoff} = \frac{\text{(Makeup Solids)}}{\text{(Max. allowable boiler TDS)} - \text{(Makeup Solids)}} \times \text{(Makeup for evaporation)}$$

EXAMPLE:

Boiler pressure = 475 psi
Total evaporation = 100,000 lb per hr.
Makeup solids = 250 ppm
Blowoff solids = Max. allowable boiler TDS 2500 ppm according to ABAI
Condensate returns = 50 per cent of total evaporation, or 50,000 lb per hr.
Makeup for evaporation = 50,000 lb per hr.
$250 \times 50{,}000$ lb per hr.
Blowoff = 2500 — 250
= 5500 lb per hr.
Total Makeup = Makeup for evaporation + blowoff
= 55,550 lb per hr.
Feedwater = Condensate returns + total makeup
= 105,550 lb per hr.

For determining the blowoff based on maintaining a given silica concentration in the boiler salines with a given silica concentration in the treated makeup, use this formula:

$$\text{Blowoff} = \frac{\text{(Makeup Silica)}}{\text{(Max. allowable silica)} - \text{(Makeup silica)}} \times \text{(Makeup for evaporation)}$$

3. Using Curve 1 and knowing the total evaporation, determine the actual pounds per hour of blowoff.

4. Using Curve 2 and knowing the boiler pressure, determine the aproximate annual savings in millions of Btu per year. The actual dollar savings per year can then be calculated for each plant. This curve is based on 75 per cent boiler efficiency. For other efficiencies, multiply result by proper ratio.

EXAMPLE:

Boiler pressure — 400 psi.
Total dissolved solids in makeup water — 90 ppm.
Amount of makeup — 100 per cent.
Total evaporation — 50,000 lb/hr.
Allowable concentration — 3,000 ppm.
From Table 1, Blowdown = 3.1 per cent.
From Curve 1, Blowdown = 1,550 lb/hr.
From Curve 2, Annual Savings = 5,500 million Btu year.

TABLE 1. Total Dissolved Solids—Allowable Concentrations—% Blowoff

Based on 100% Makeup

% Blowoff of total evaporation

Total dissolved solids makeup, PPM	Allowable concentration, PPM						
	1000	1250	1500	2000	2500	3000	3500
10	1.0	0.8	0.7	0.5			
15	1.5	1.2	1.0	0.8	0.6	0.5	
20	2.0	1.6	1.4	1.0	0.8	0.7	0.6
25	2.6	2.0	1.7	1.3	1.0	0.8	0.7
30	3.1	2.5	2.0	1.5	1.2	1.0	0.9
40	4.2	3.2	2.6	2.0	1.6	1.3	1.1
50	5.3	4.2	3.4	2.6	2.0	1.7	1.4
60	6.4	5.0	4.2	3.1	2.5	2.0	1.7
70	7.5	5.9	4.9	3.6	2.9	2.4	2.0
80	8.7	6.8	5.6	4.2	3.3	2.7	2.3
90	9.9	7.8	6.4	4.7	3.7	3.1	2.6
100	11.1	8.7	7.2	5.3	4.2	3.4	2.9
125	14.3	11.1	9.1	6.7	5.3	4.3	3.7
150	17.7	13.6	11.1	8.0	6.4	5.3	4.5
200	25.0	18.8	15.4	11.1	8.7	7.2	6.1
250		25.0	20.0	14.3	11.1	9.1	7.7
300			25.0	17.6	13.6	11.1	9.4
400				25.0	19.0	15.4	12.9
500					25.0	20.0	16.7
600						25.0	20.6
700							25.0

XUM

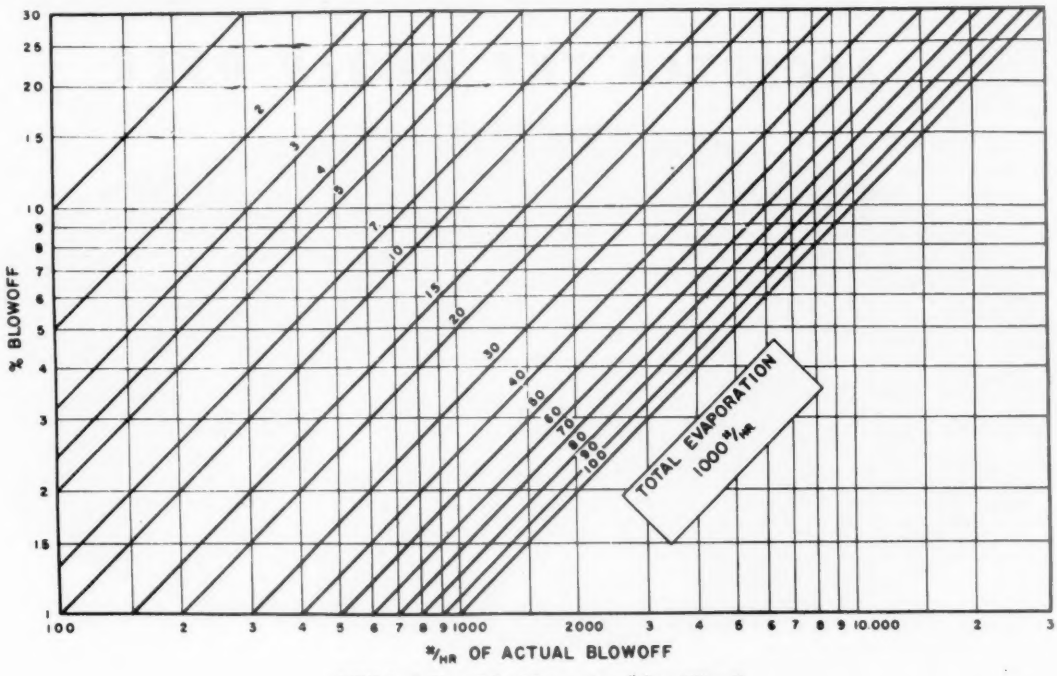
MAKE WAY FOR THE PIPELINE

Keep clearing schedules on time and save money doing it. Get the dependable, easy-to-handle Homelite chain saws. They have more power per pound than any other chain saw ever developed. They rip through 20 inch trees in 20 seconds, fell the big ones five feet or more in diameter with ease. But most important they stand up under the grind . . . they keep cutting day after day, from morning to night. Down time and costly job stoppages are practically eliminated . . . maintenance costs are reduced to a minimum. Ask your Homelite representative for a free demonstration or write for folder today.

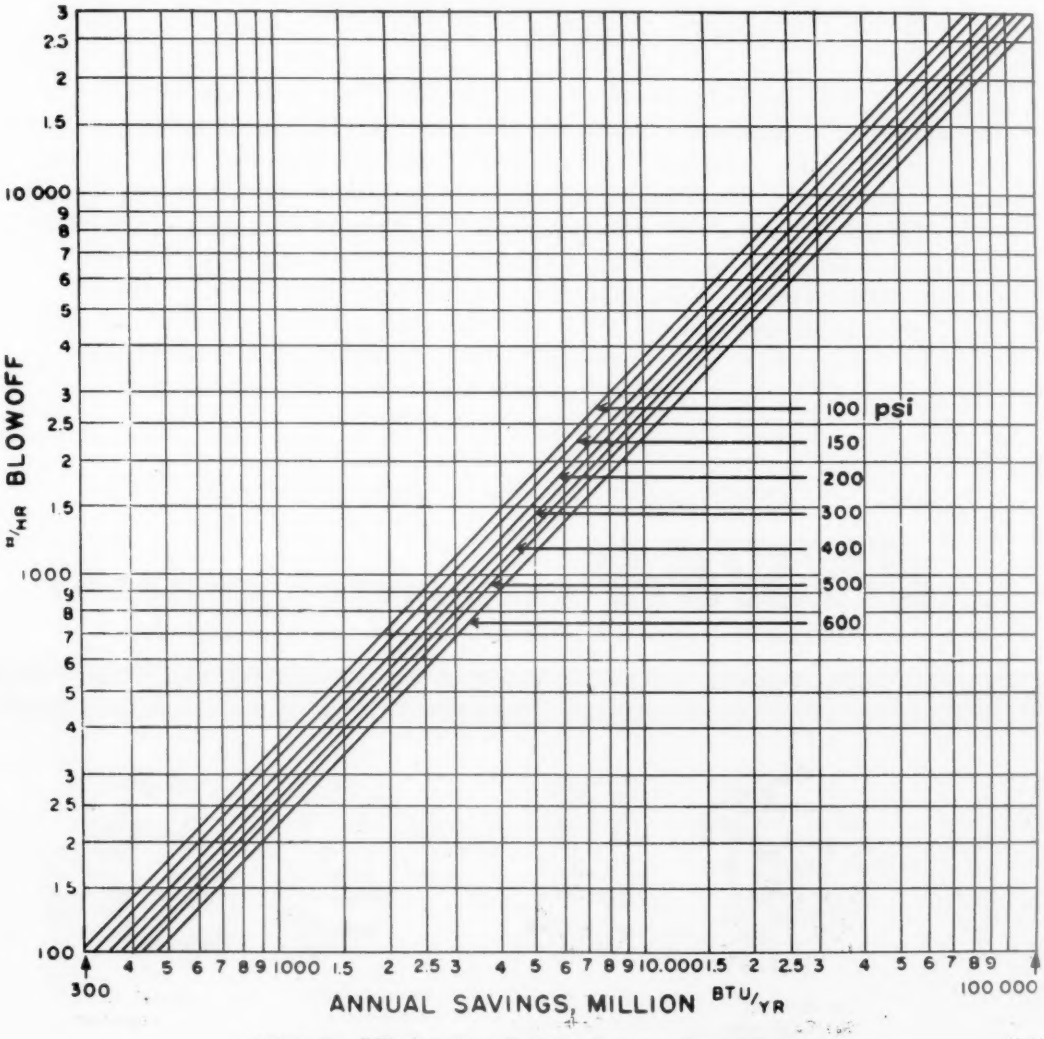
HOMELITE CORPORATION

4706 Riverdale Avenue Port Chester, N. Y.

BTU Savings From Continuous Blowoff Heat Recovery



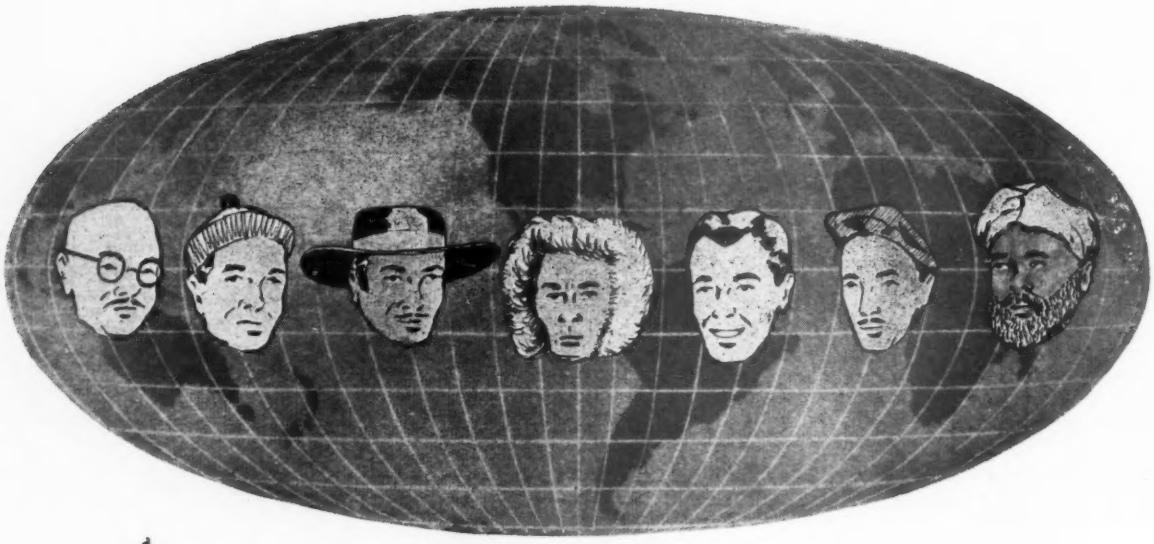
CURVE 1: % Blowoff, Total Evaporation, #/hr. of Blowoff



CURVE 2: #/hr. of Blowoff, Boiler Pressure, Annual Savings

ENSIGN CARBURETORS

ACCEPTED THE WORLD OVER



IN ANY LANGUAGE, ENSIGN means EASY STARTING
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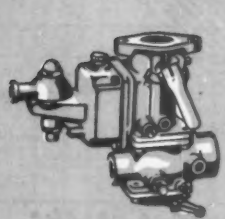

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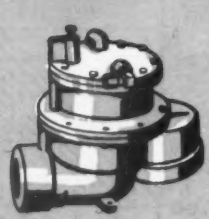

Model "B" Fuel Regulator

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LAUGH with BARNEY

Inflation has set in so much that if you tell a woman she looks like a million dollars she thinks you are insulting her.

Sometimes a pinch of salt can be improved by dropping it into a glass of beer.

How's your new girl?
Not so good.
You always were lucky.

One great obstacle to marriage these days is the increasing difficulty in supporting the government and a wife on one income.

Most girls would rather be looked over than overlooked.

For years the two sexes have been racing for supremacy. Now they have just settled down to neck and neck.

Herman Peterson, author of "Country Chronicle," moved on a farm in upper New York state because he thought it would be a good place to write. When an inquiring neighbor asked between spurts of tobacco juice, what crops the stranger intended to raise, Peterson was momentarily stumped. Then he happened to recall what his wife had said about the city being no place to bring up children.

"I'm going to raise children," he said brightly.

The farmer spat meditatively, "Around here," he said, "we look on that as a sideline."

Driving Teacher: "And when I put my hand out the window like this, what does it mean?

Woman Student: (hopefully) "The window's open?"

"Jean," moaned the long-suffering husband. "You promised me you wouldn't buy any more new dresses. What made you buy this one?"

"The devil tempted me," replied Jean demurely.

"Why didn't you say 'Get thee behind me, Satan'?" he asked.

"I did," was the sweet reply, "and then he whispered over my shoulder, 'My dear, it fits you beautifully at the back'."

In the days when a woodshed stood behind the American home, a great deal of what now passes for juvenile delinquency was settled out of court.

A young husband who had agreed to buy a vacuum cleaner was disturbed when he found his wife had ordered the deluxe model instead of the standard.

"But dear," his wife explained, "it won't cost any more. All we have to do is pay a little longer."

Two men met who hadn't seen each other for some time, but one had heard that his friend had recently been jilted. Sympathetically he said, "So you loved and lost, my boy. Too bad."

"On the contrary, old man," said the other cheerfully. "I came out ahead. She returned all my presents and accidently included two from some other guy."

The boy was doing his best, loaded down with a wash pot on his back, a chicken under his arm, cane in his hand and leading a goat. His girl hesitated as they came to the woods, saying:

"I'm afraid to walk with you in there. You might try to kiss me."

"How could I," the boy assured her. "Look at all I'm carrying."

"But you could stick that cane in the ground, tie the goat to it, then put the chicken under the wash pot."

We heard a disappointed wolf say, "She's a good girl, it's true, but does she have to be a fanatic?"

Women have a keen sense of humor. The more you humor them, the better they like it.

A Tennessee distiller sent a gift keg of whisky to an improvident friend up in the hills for Christmas. Along about the end of January, the beneficiary dropped in on the giver and hinted that more liquor would be welcome.

"Aren't you overdoing it a little?" asked the distiller. "As I recall, I sent you a whole keg just a few weeks ago."

"That's right, sir," admitted the mountaineer, "but you got to remember a keg of whisky don't last long in a family that can't afford a cow."

In the pot of life, if you want to keep cooking, you've got to keep stirring.

"How much sleep do you ordinarily require?" asked the doctor.

"About five minutes more."

"And after Goldilocks ate the porridge," read the baby sitter, "she went upstairs and saw three beds . . ."

"Jeepers," interrupted Junior, "I'll bet the porridge had been spiked!"

A man had barely paid off his mortgage on the house when he mortgaged it again to buy a car and then borrowed money to build a garage. "If I do make the loan," said the broker, "how will you buy gas for the car?"

"It seems to me," the man replied curtly, "that a fellow who owns his own house, a car and garage should be able to get credit for gasoline."

A man went to the bar and ordered a Martini, drank it, chewed up the bowl of the glass, and threw the stem over his shoulder. He continued this for about six Martinis and noticed that the bartender was staring at him.

"I guess you think I'm crazy, don't you?" he asked.

"I sure do," the bartender replied, "the stems are the best part."

During a severe electrical storm, the parent of young Jimmy, age 5, thinking he might be awake and be frightened, looked into his room. He opened his eyes and mumbled, "What's Daddy doing with the television set now?"

It's much better to sit tight—than to attempt to drive in that condition.

The Morse Code for the Bikini bathing suit is two dots and a dash.

Money is something that things run into and people run out of.

Confucius probably say: Who say I say all the things they say I say?

Our major cities have become so congested with cars and trucks that there are only two kinds of parking left—illegal and no.

Two farmers at a county fair were fascinated by a booth where little celluloid balls bobbed on top of water jets. Customers were offered substantial prizes if they succeeded in shooting any one of the balls off its perch. One of the farmers spent six quarters in a vain attempt to pick off one ball. Finally his friend pushed him aside and picked up the rifle.

"Watch how I do it," he said.

He took a single shot. All six balls disappeared.

As they walked away from the booth laden with prizes, the unsuccessful one marveled.

"How did you ever do it?" he asked.

"It just took knowing how," explained the winner. "I shot the man working the pump."

Life is cruel to men. When they're born, their mothers get compliments and flowers; when they get married the bride gets presents and publicity; and when they die, their wives get the insurance and the winters in Florida.

The best flings in life aren't free.

A man was feeling very bad. He was worrying because he had just lost 110 pounds. She was a blonde.

"I'm off to the races," said the horseplayer excitedly, "and I do hope I break even. I sure need the money."

Two drunks were leaning over a bar telling intimate stories of their life. "I weighed only a pound when I was born," said one.

"Only a pound! Did you live?" asked the other.

"Did I? You should see me now!"

A woman is young until she takes more interest in how her shoes fit than her sweater.

A young man stared into the mirror one morning and noted his bloodshot eyes, resolved to never go into a bar again. That television, he muttered, is ruining my eyes.

The arm of a well-dressed, generous-looking passerby was clutched by a beggar who whined, "Give me five cents, kind sir, for a cup of coffee?"

The other looked him over carefully. "Why should I give you five cents?" he asked.

"Because, sir, prior to my terrible catastrophe, I, too, enjoyed business success and prosperity," was his reply. "I was an industrious worker. On the wall above my desk I had a motto which read. 'Think Constructively — Act Decisively.' The money poured into my coffer. And then . . . and then . . ."

"Yes? What happened?"

The beggar's frame shook convulsively. Tears appeared in his eyes.

"The cleaning lady burned my motto."

BOOKS ★

Selected Values of Physical and Thermodynamic Properties of Hydrocarbons and Related Compounds, *American Petroleum Institute Project 44, Carnegie Press, Pittsburgh, Pennsylvania. Pages, 1050. Price, $7.00.*

This extensive volume by the API is the culmination of ten years of work, ending in 1952, by a group of the nation's top chemists, and reflects the scope of hydrocarbon research being carried on today. The book is a compilation of data of interest to the petroleum industry covering physical, thermodynamic, and infrared, ultraviolet, Raman, and mass spectral properties of hydrocarbons and all related compounds. The extent of the coverage of the scientific and technical literature by the project is indicated by the fact that the number of papers included in the list of references is well over 2500.

The Romanian Oil Industry, *by Constantin N. Jordan, New York University Press, Washington Square, New York 3, N. Y. Pages, 357. Price, $10.00.*

Although the oil fields and refineries of Romania are relatively small as shown in the overall world oil picture, the strategic position in the event of war makes it an area of utmost importance. In any European conflict or transfer of power, past, present, or future, Romania's natural resources figure prominently.

The author, born and educated in Romania, with years of experience with a leading Romanian oil company, is considered an authority on the petroleum industry there. This publication contains statistical data pertaining to production figures, equipment and supplies; labor force; transport, marketing, and consumption; communization of the industry; and oil reserves. It is factual, easily readible, and timely. The work is documented with tables, graphs, and a map of the oil fields.

It was especially prepared for the Mid-European Studies Center of the Free Europe Committee, Inc., and with the cooperation of the research staff of the American Petroleum Institute.

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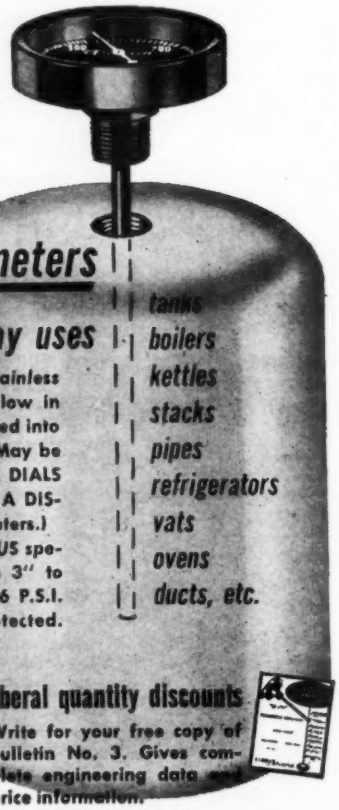

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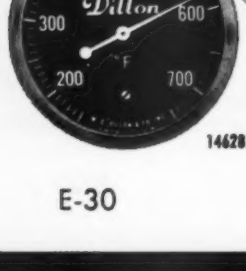

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He Lived for Adventure, *by Campbell Osborn, Campbell Publishing Company, 330 Woodward Building, Washington, D. C. Pages, 268.*

A book of travel, written in autobiographical style, the author carries the reader from the Oklahoma oilfields around the world, exploring many subjects and many vocations. It is a preliminary edition relating the experiences with noted governmental and military leaders and gives a good insight into the thinking and economic backgrounds of peoples from Bermuda to Burma, as seen through the eyes of this writer.

Some Fundamentals of Petroleum Geology, *by G. D. Hobson, PhD, Oxford University Press, London, and New York. Pages, 140.*

Author Hobson, a member of the staff of the geology department of the Imperial College of Science and Technology, has effectively presented an overall, brief, explanation of the nature of oil accumulation, together with ideas on the origin of oil and its aggregation into a commercial oil pool.

This book was prepared for a student of geology or for those already familiar with the oil industry, but lacking in geological theory. Included are discussions on chemical, physical composition and properties of oil, natural gas and natural gasoline, the origin of petroleum, as well as explanations of current concepts of reservoir pressures and oil migration and accumulation. Such subject as fluid loss, formation volume factors, porosity, permeability, and closure also receive attention. It is up to date in content, worldwide in scope, and excellent in presentation.

Manufacture and Application of Lubricating Greases, *by C. J. Boner, Reinhold Publishing Company, New York City. Pages, 977. Price, $18.50.*

The first book on lubricating greases since the famous old authority, *Lubricating Greases,* by E. N. Klemgard, this nearly a thousand pages is the most replete volume, or series of volumes on this highly complicated subject ever published. Authored by one of the two or three really top authorities in the entire field, Boner has outdone himself in the wealth of data presented.

Among innumerable other outstanding items, he has, we believe, for the first time, presented a workable, intelligible, practical definition of the perplexing—for the non-authority—word, "Thixotropy." His suggested definition (p. 65) is "Thixotropy in lubricating greases is that property which is manifested by a decrease in consistency as a result of shearing, followed by an increase in consistency starting immediately after the shearing is stopped." In this context the meaning of "shearing" is obviously "stirring" or otherwise mixing up the body of the grease.

No mere brief review can do the book justice; starting with "structure and theory," the author assembles in turn the working materials of the industry, that claims some 115 manufacturers (he says) in the U. S. A.: Additives, Raw Materials, Processes, Manufacturing Equipment. Then he plunges into the innumerable ramifications of the industry's problems and products; Aluminum, Barium, Calcium, Lithium, Sodium, Lead, Strontium and other base greases. To complicate an already highly complicated technology, the industry has introduced many, many mixed-base greases; the number of permutations of properties and effects on properties of this mixing of components beggars description or enumeration. The author shows many specifications and compositions of various type greases; discusses the advantages and disadvantages of mixing primary components, in affecting, improving or degrading grease properties innumerable. Photomicrographs, especially since the adaptation of the electron microscope, have brought to light to a degree hitherto undreamed of the structure, properties and characteristics of lubricating greases and their components.

Two of the foremost chapters are Analysis of Lubricating Greases, and Tests of Lubricating Greases and Their Significance. Here both the *modus operandi* and the pertinent items to be determined and measured are included along with discussion of standard equipment employed, needs to be met, and interpretation of results; this last is without doubt the most important of all the details presented.

The book cannot be appraised satisfactorily in any review; only by reading and studying its contents can we realize the real value of this monumental work.

Rotary-Percussion Drilling, *by Emory N. Kemler, Summary Reports, P. O. Box 176, Spring Park, Minnesota. Pages, 114.*

Demand for higher drilling rates for very hard formations and straighter holes is responsible for many innovations in drilling procedure, notable of such is the rotary-percussion method. Because of its recent and fast changing development, there is little technical literature to guide research and drilling engineers. This manual was produced to fulfill this purpose through a discussion of literature, patents and listings of patent abstracts on pneumatic and other rotary-percussion devices and their inventors and authors.

PERSONALS

Lawrence Wolff, 59, executive assistant to the vice president of Union Oil Company of California, has retired from the company after 43 years of service.

John R. Rock of Berkeley, California, has been promoted to assistant supervisor of employee relations of Tide Water Associated Oil Company's Western division, replacing **Claude E. Fountain** who has been made assistant to the manager of the company's nationwide employee relations program.

Lewis W. Douglas, former ambassador to Great Britain and internationally known American businessman, has been elected a director of Continental Oil Company. **P. Malozemoff,** New York City, director and president of Newmont Mining Corporation, was also elected a director. He replaced **Charles F. Ayer,** who has retired after 26 years as a Continental director.

J. W. Ferguson, for the past two years assistant manager of Continental's coordinating and planning department, has been promoted to acting manager. He succeeded **C. B. Wentz,** who was recently promoted to assistant general manager of Continental's southern region. Ferguson, who joined Conoco as senior analyst in 1952, was previously associated with The U. S. Bureau of Mines in gas engineering capacities.

Oswald Newell, Jr., senior process engineer in Continental Oil Company's manufacturing department, has been selected from American industry to receive a 1955-56 Sloan Fellowship at the Massachusetts Institute of Technology. Nowell is the fourth Conoco man in six years to receive a Sloan Fellowship.

H. Maurice Banta has been named technical adviser at Battelle Institute, Columbus, Ohio. Long associated with technical studies of petroleum and gas drilling, production and drilling equipment, and pipe line installation and maintenance, he will advise the Institute's clients on the formation of their research programs. Banta has directed research studies at Battelle since 1942 and is the author of numerous metallurgical papers.

J. Frank Drake, after serving 17 years as president of the Gulf Oil Corporation, 5 years as chairman of the board, and, during the past two years, as chairman of the executive committee, has retired from the last-named position. He continues, however, as a member of Gulf's board of directors and of the finance committee of the board. He first joined Gulf in June, 1919, as assistant to the president. In 1923, he left Gulf to become president of the Standard Steel Car Company. He returned to Gulf as president in April, 1931. Five years later, he was elected chairman of Gulf's executive committee.

Drake is a director of Pullman, Inc.; Pullman Standard Car Manufacturing Company; Armee Steel Corporation; Mellon National Bank and Trust Company; the Chase Manhattan Bank; Rockwell Manufacturing Company; Trailmobile Company; M. W. Kellogg Company and other corporations.

W. G. Moore, Gulf, a veteran of more than 20 years with the company, has retired. Moore has served as assistant to president under Drake (1934 to 1948), **S. A. Swensrud** (1948 to 1953), and more recently under **W. K. Whiteford,** Gulf's current president. During his service to Gulf, Moore's activities were concerned largely with the economics and coordination of the company's major operations. More recently he has been actively engaged in the development of the company's growing petrochemical interests.

Professor Marcello Boldrini, chairman of the general organizing committee of the Fourth World Petroleum Congress, in a recent press conference in Rome; attended by foreign and Italian correspondents, outlined general plans and aims. In the group flanking Boldrini are: At his right, the Gr. Uff. D'Amelio and Marchese Pennavaria, both vice chairmen of the general organizing committee; at his left, Dr. Cazzaniga, vice chairman of the general organizing committee and Dr. Muston, general secretary of the congress.

William Ewing Eadie, who has been appointed the managing director of the Burmah Oil Company, has served with that company for 34 years. He is a chartered accountant by profession. He joined the Burmah Oil Company in 1921 and proceeded to Burma. On the formation of Burmah-Shell in 1928 he was transferred to that company as chief accountant and took up residence in Calcutta. In 1941 he was transferred to the head office in London of the Burmah Oil Company and in 1948 became chief accountant. Two years later he joined the Board as an executive director and in 1951 was appointed assistant managing director. Eadie replaced **W. E. V. Abraham,** who retired at his own request from the managing directorship, but retained his directorship.

W. E. Eadie

John M. Sprague has been named a vice president of The Carter Oil Company. Sprague, who has been manager of Carter's eastern divison operations in Illinois, Indiana, Michigan, and Kentucky, will make his headquarters in Tulsa, Oklahoma. **R. C. Curtis,** formerly production manager of the eastern division, succeeded Sprague.

Dr. Kieffer Davis, medical director of Phillips Petroleum Company, has been installed as president of the Industrial Medical Association. Davis, who joined Phillips in 1947 as head of the company's medical department, has inaugurated a program of industrial medicine that now includes preventive and constructive as well as curative practices. He was among the first in the industry to use a mobile medical unit as a means of reaching field employees for periodic health determinations.

Gustave L. Hoehn, Jr., and **Phillips S. Landis** have been awarded Socony Mobil Oil Company's 1955 incentive fellowships. Hoehn is a senior research electrical engineer at Magnolia Petroleum Company's field research laboratories at Dallas, Texas. Landis is a senior research chemist at Socony's laboratories at Paulsboro, New Jersey. Socony Mobil, whose corporate name was recently changed from Socony-Vacuum, established these annual fellowships in 1947 "to improve the academic training of their laboratories' employees who have shown more than usual ability and proficiency . . ."

D. L. Hussey has resigned from the board of directors of Iraanse Aardolie Raffinage Maatschappij (Iranian Oil Refining Company) N. V. and **P. E. Kuhl** has been appointed to fill the vacancy on the board.

J. E. Roth

J. H. Sembower

J. E. Roth, vice president and general manager of the central division of Tide Water Associated Oil Company at Tulsa, Oklahoma, has been elected to the board of directors of the American Petroleum Institute. He replaced **E. H. Salrin,** retired vice president of Tide Water Associated.

J. H. Sembower, West Coast public relations manager for Shell Oil Company, has moved from San Francisco to Los Angeles. **P. W. Harvey,** who has been the Los Angeles representative for the past year, has been transferred to San Francisco. A series of transfers in Shell's public relations department recently established Los Angeles as headquarters for West Coast activities.

T. F. Scoggins has been named to replace Harvey in Los Angeles. Scoggins has been the company's public relations representative in New Orleans, Louisiana, during the past three years. A fourth move sent **W. L. Gordon** from San Francisco to a newly created northwest public relations post in Seattle, Washington.

Elmer F. E. Schmidt has been elected president of Overland Oil, Inc., Denver, Colorado, oil and uranium company. He was formerly vice president and general manager of the Lone Star System.

Winfield Morten, former president of Overland, has been elected chairman of the board.

S. B. Irelan, president of Cities Service Oil Company, has been elected a member of the Purdue Research Foundation as an alumni research counselor. Irelan is a graduate of Purdue and is the recipient of an honorary doctorate in engineering.

M. Darwin Kirk, who was elected vice president and general attorney for Sunray Oil Corporation in March, 1951, fills the same post with Sunray Mid-Continent Oil Company.

Kirk was graduated from the University of Oklahoma in 1923, and obtained his LLB degree from OU in 1925. He joined the legal staff of Phillips Petroleum Company in September, 1928.

Dr. Carlos Lander Marques has been appointed manager of the industrial relations department of Creole Petroleum Corporation in Venezuela. **Lawrence P. Birney** has been designated assistant manager and began his new duties in June. Creole's new industrial relations manager replaced **Hal J. Wright,** who was recently elected a member of the company's board of directors.

E. D. Brockett, Jr., has been elected a vice president of Gulf Oil Corporation. He will be manager of the company's Houston, Texas, production division, succeeding Vice President **B. C. Belt,** who has announced retirement plans. A petroleum engineer by profession, Brockett joined Gulf as a roustabout in 1934.

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DEATHS

Dr. Gustav Egloff, one of the world's foremost petroleum scientists and director of research for Universal Oil Products Company, died recently in Alexian Brothers Hospital, Chicago, Illinois, following a brief illness. The dynamic "Mr. Petroleum" was active almost to the end and had visited his office just a few days before his death.

Dr. Egloff was the oldest employee in point of service of Universal Oil Products Company, having joined on February 15, 1917, when the fledgling company had a small research building in Independence, Kansas. He had held the post of director of research for many years, and had seen the refining industry revolutionized.

Born in New York of Swiss parents, Dr. Egloff attended Cornell University and Columbia University.

Later he frequently startled the scientific world as well as the general public with predictions of revolutionary developments 10, 15 or 20 years before their occurrence. Years before nylon, orlon and dacron, for example, became household words and every day articles of wearing apparel, Dr. Egloff predicted with supreme confidence that synthetic fibers would be created out of petroleum by-products.

Dr. Egloff was the author of 650 articles relating to the petroleum industry and the chemistry of hydrocarbons, particularly the cracking and refining of oil. Approximately 300 patents had been credited to him in the United States and abroad relating to the processing of petroleum oil, coal, shale oil and chemical derivatives of hydrocarbons. He was the author of a number of books which are widely used by petroleum scientists and technologists. Among them are *Thermal Reactions of Pure Hydrocarbons, Catalysis, Isomerization of Pure Hydrocarbons, Alkylation of Alkanes,* and a five-volume work *Physical Constants of Hydrocarbons.*

Honors came to him by the score, both from scientific societies and from governments around the world. In October of 1953 he was one of three invited foreign lecturers at the 75th anniversary celebration of the Chemical Society of Japan, and was the only American to address the society. Last October 7 he was awarded the coveted Karl Engler Medal at the German Institute of Petroleum and Coal Congress in Essen—the first scientist living outside of that country ever chosen for the award.

Among other honors conferred upon him were the Octave Chanute Medal of the Western Society of Engineers in 1939-40; his nomination as one of the "Modern Pioneers" by the National Association of Manufacturers in 1940; the Gold Medal of the American Institute of Chemists in 1940; Distinguished Service Award of the National Research Council in 1941; a fellowship in the Royal Society of Arts of Great Britain in 1950, and honorary degrees of doctor of science confered by the Polytechnic Institute of Brooklyn, Illinois Institute of Technology, and the Philadelphia College of Pharmacy and Science.

L. E. Emerich, director of marketing for Leeds & Northrup Company, died recently after an illness of several months. Emerich, a graduate of Carnegie Institute of Technology, joined Leeds & Northrup in 1922 as a sales engineer.

Robert C. Woodward, who had retired in December, 1954, after serving 20 years as chief metallurgist for Bucyrus-Erie Company, died at Columbia Hospital in Milwaukee, Wisconsin, after a short illness. After joining Bucyrus-Erie in 1935, Woodward gained experience in cable tool drilling problems and had planned to offer part-time consultant service in retirement. He had become known as a speaker on drilling problems and was the author of a recent paper on "Heating, Forging, and Hardening Churn Drill Bits."

Frank A. Hiter, senior vice president of Stewart-Warner Corporation since 1944 and head of the company's Alemite and Instrument division died recently at Wesley Memorial hospital, Chicago, Illinois. Hiter would have completed 35 years with the Alemite lubrication products division of Stewart-Warner next December. He started as assistant sales manager of the Alemite Corporation in 1920, four years before that company was purchased by Stewart-Warner. He became a vice president of Stewart-Warner in 1933 and a director in 1942.

Roy J. Miller, an executive of the former Julius Hyman Company for five years, died recently in Denver, Colorado, from injuries suffered in a traffic accident. Miller, who formerly resided in Denver, had moved to California two years ago when the Hyman Company was taken over by Shell Chemical Company.

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—Plymouth Oil Company Annual Report.

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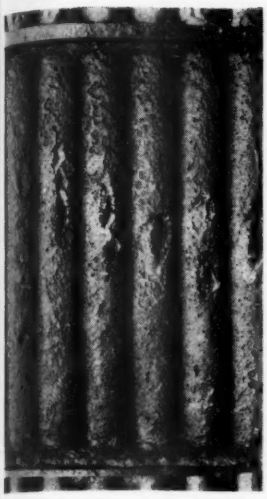

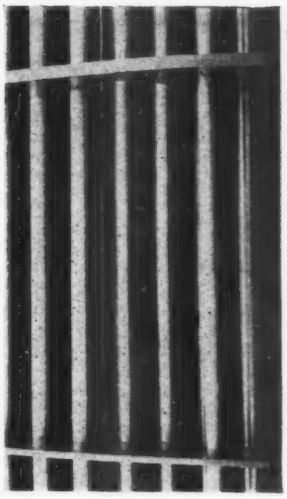

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How do you save? First, out-of-service time is cut sharply because quick-penetrating Oakite detergents rout soils up to 75% faster than manual cleaning methods. Second, by reducing time and work, you're saving on production costs. And third, you're restoring to near-new efficiency equipment that might have been scheduled for the scrap heap.

You can learn more about modern Oakite cleaning by writing for the FREE booklet, "What Petroleum Men Should Know to Simplify Cleaning." Get your copy by writing Oakite Products, Inc., 48 Rector Street, New York 6, N. Y.

Technical Service Representatives in Principal Cities of U. S. and Canada

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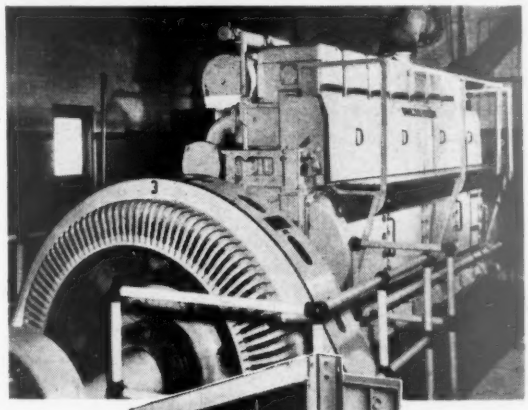
PETROLEUM SERVICE DIVISION



Nordberg Diesel rated 1060 hp., cooled by Young Radiators

Young Radiator Company Jacket Water Cooler serving Nordberg Diesel

Cool, ventilate, heat

Iowa power plant with YOUNG Mono-Weld radiators

Sioux Center, Iowa Municipal Power Plant has taken full advantage of two Young Radiator Company Jacket Water Coolers used to dissipate engine heat in a Nordberg Supercharged Diesel engine developing 1060 hp.

Rejecting engine heat up to 1,530,000 B.T.U. per hour, the Young Radiators utilize this heat to reduce plant heating costs.

Doors between engine and shutter-equipped cooler rooms may be opened or closed to draw hot air out of engine room in summer for ventilation or deliver hot air for winter plant heating.

Young *Mono-Weld* water cooling capacities range from 500,000 to 2,300,000 B.T.U. per hour. For further details write or call Young Radiator Company today.

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Heat Transfer Products for Automotive, Aviation and Industrial Applications. Heating, Cooling, Air Conditioning Products for Home and Industry.

Executive Office: Racine, Wisconsin, Plants at Racine, Wisconsin, Mattoon, Illinois

OIL and GAS TRADE NEWS

Schlumberger Adds Branches

Three new service locations—two in Kansas and one in North Texas—have been opened by Schlumberger Well Surveying Corporation. Offices were opened in Wakeeney, Kansas, with R. W. Clum as manager, and at Medicine Lodge with Gayle T. Bradshaw as manager. The new service point in North Texas is at Sherman under direction of R. S. Beaty.

Pearce Company Organized

Pearce Equipment Company, Inc., has been organized in Houston as a subsidiary of Waukesha Sales and Service, Inc. and will be exclusive distributor in the Houston-Gulf Coast area for Clark Equipment Company's Michigan line of construction machinery equipment.

Naresco Representative Named

The Hainge Company, Incorporated, Houston, has been appointed Gulf Coast sales representative by Naresco Equipment Corporation, equipment sales subsidiary of National Research Corporation. The Company will sell the entire line of high vacuum equipment manufactured by the Equipment division of National Research Corporation.

White Buys Diesel Division

The White Motor Company, manufacturer of motor trucks, has also become a major producer of diesel engines, through the acquisition for cash of the property, business, inventory and other assets of the diesel engine division of The National Supply Company.

Security Moves

The executive offices of Security Engineering division, one of the Dresser Industries, have been moved from Whittier, California to Dallas, Texas. Security's management is headquartering in the Atlantic Building at Dallas pending completion of executive offices.

Fairbanks, Morse Enlarges

Fairbanks, Morse and Company has formally opened a new sales and service headquarters for a seven-state area including Connecticut, New York, New Jersey, Eastern Pennsylvania, Maryland, Delaware and Virginia.

New Ampco Distributors

The safety tool department of Ampco Metal, Inc., Milwaukee, Wisconsin has announced the appointment of two new Class "A" Distributors. The Giller Tool Supply Company, Inc., Dallas, Texas and The Mississippi Foundry and Machine Company, Inc., Jackson, Mississippi are the appointees.

Bjorksten Records Progress

A summary of 10 years' progress and an analysis of plans for the next decade are contained in a report just issued by Bjorksten Research Laboratories of Madison, Wisconsin, Chicago, Illinois, New York, New York, and Washington, D. C. Operated for sponsored industrial research, the Laboratories have made numerous contributions to widely diversified fields.

Ideco Named Jones Outlet

Mason B. Jones, president, The S. M. Jones Company, has announced the appointment of Ideco, one of the Dresser Industries, as the exclusive export distributor of Jones Sucker Rods.

Canadian Outlet Named

Appointment of Process-Instrument Systems, Ltd., as Canadian representatives for its Autronic Process Controls Division for Ontario and all eastern provinces of Canada is announced by The Swartwout Company, Cleveland. The power plant equipment division of The Swartwout Company will continue to be represented in Canada except for British Columbia by Dominion Flow Meter.

IRE Uses Closed TV

The most extensive closed circuit television system to provide a message paging service at a trade show was installed at the Radio Engineering Show of the Institute of Radio Engineers held at the Kingsbridge Armory and Kingsland Palace in Clifton, New Jersey.

Eight monitors were in operation, with messages for visitors and exhibitors being received at a central switchboard and the names posted on a large board standing before the TV cameras. These names are flashed simultaneously on all eight receivers. The TV receivers were supplied by Capehart-Farnsworth Company; the TV camera equipment by Farnsworth Electronics Company, and the coaxial cable by Federal Telephone and Radio Company, all divisions of International Telephone and Telegraph Corporation.

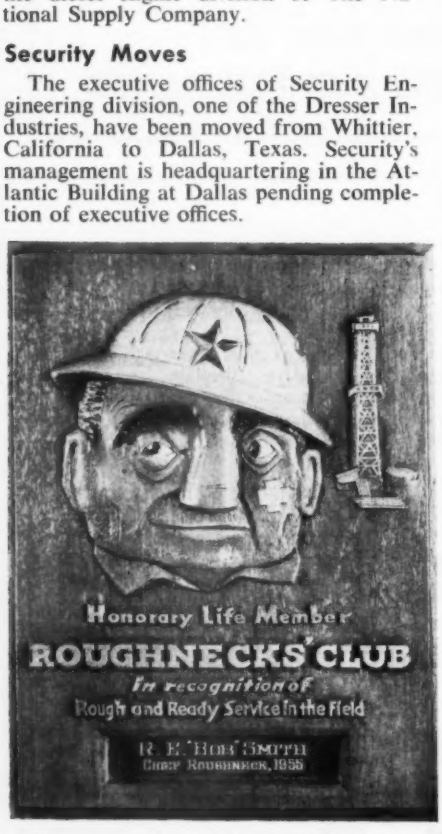
Delta Enters New Field

Delta Tank Manufacturing Company, Inc., subsidiary of General Gas Corporation, announced its entry into the production of oil-gas separators for use in oil fields and unveiled a new line of spherical units which can process up to 16,000 bbl of crude oil daily. The Delta spherical separators have been field tested by a number of major oil companies.

Baroid Opens Retail Store

A store devoted entirely to the sale of mud has been opened at 19551 Santa Fe Avenue, Long Beach, by the Baroid division of National Lead Company. This is its first direct sales store to serve the oil industry. The firm supplies clays, chemicals, and other materials used in special muds needed for oil well drilling.

The new store, near Long Beach, is an industrial innovation designed to give comprehensive direct-from-manufacturer service in the Huntington Beach, Seal Beach, Long Beach, Wilmington, Signal Hill and adjacent fields.



Oilman R. E. (Bob) Smith, Houston, Texas, was named Chief of the Roughneck's club for 1955 in ceremonies at Lone Star Steel Company's integrated steel mill in Northeast Texas. Smith, right, receives a handsome plaque and jeweled lapel emblem from E. B. Germany, Lone Star president. The Roughnecks' club is dedicated to the recognition "of the pioneers of yesterday and today whose perseverance and courage have made our nation the world's leaders in petroleum." For more details see E-37.

Poole-Pritchard Formed

A new design, engineering, and construction organization, the Poole-Pritchard Company, Ltd., has been formed with offices in Edmonton, Alberta, Canada. The company's area of operations will be in western Canada from the Great Lakes to the Pacific. The organization is a combination of the Poole Construction Company, Ltd., of Edmonton and J. F. Pritchard and Company of Kansas City.

ALCO Adds Fin Tube Process

American Locomotive Company has acquired the Carter Craft fin tube process, a new method of heliarc welding longitudinal fins to tubes for use in heat exchangers. The company has also announced production of a new line of fin tube heat exchangers for the petroleum, chemical, petrochemical and power industries, which employ the advance-design tubes in their construction.

BrakeSol, Inc. Appointed Agent

BrakeSol, Inc. has been appointed sales and service representatives for McCord Chemical Pumps and parts. McCord has also put in a warehouse dock at Odessa, Texas. Other warehouse locations will be announced later.

Dore' Companies Expand

Dore' Companies have started construction on additional plant facilities in their present location, 5406 Schuler Street, Houston, Texas. The addition is a 3200 sq ft steel and corrugated asbestos building, which will house machinery and equipment for molding and finishing Teflon, Kel-F and nylon shapes.

BS&B Develops Method

Black, Sivalls and Bryson, Inc., has recently developed a new method for sizing valves for liquid, steam, and gas applications. The new method utilizes two basic "tools" for accurate sizing: the Size-O-Graph, to determine what the valve must do, and CV ratings, to determine what the valve will do. These "tools" are based upon thousands of flow tests performed on all sizes and types of BS&B controls.

American Hoist Acquires Laughlin

The acquisition of the Thomas Laughlin Company of Portland, Maine, has been announced by American Hoist and Derrick Company of St. Paul, Minnesota. The merger is the first step of a planned expansion program authorized by American Hoist stockholders a year ago.

Climax Adds Distributors

Climax Engine and Pump Manufacturing Company has recently set up 12 new distributor locations. New distributors are Sweeney Brothers, Williston and Fargo, North Dakota; Cullander Machinery Company, Belzoni, Mississippi and West Memphis, Arkansas; Equipment Service Company (irrigation engines only), Pecos, Texas; Henkle and Company (irrigation engines only), Garden City, Kansas; Landes, Zachary and Peterson, Denver, Colorado, Billings, Montana, El Paso, Texas, Albuquerque, New Mexico, Casper, Wyoming, and Salt Lake City, Utah.

L.O.F. Plant Toured

A tour of three midwestern plant facilities was a highlight of the first general sales meeting of the new L.O.F. Glass Fibers Company.

Carl White, Jr., left, former president of Franks Manufacturing Corporation of Tulsa, shows R. A. Baker, center, new Franks president, about the Franks plant following the sale of Franks to the Cabot Shops, Inc., of Pampa, Texas. C. C. Simmons, Franks Works Manager, looks on. White remains with the company in an advisory capacity.

Tuboscope Expands in Merger

Effective May 1 the services, equipment, and experience of Subsurface Engineering Company, specialists in developing data for reservoir analysis, is merged into Tuboscope Company. This merger will result in a stronger and larger organization which will be able to carry out the research and field work needed to serve the expanding oil industry.

BJ, B-W Merger Near

R. C. Ingersoll, president of Borg-Warner Corporation, and E. S. Dulin, president of Byron Jackson Company, announce that after negotiating for some time they have agreed and will recommend to their respective boards of directors that the two companies merge. Dulin has agreed to also recommend that the Byron Jackson shareholders approve the plan of merger. The merger is to be accomplished on the basis of four shares of Borg-Warner for five shares of Byron Jackson.

Chiksan Has Sales Meet

Sales department of Chiksan Company held a three-day sales conference at the main office and plant at Brea, California, April 18 through 20, with 30 Chiksan sales personnel present. Canada, the Atlantic seaboard, the Midwest and Southwest were represented, with two members of the Weco division in Houston present.

Chiksan's newest products were unveiled and demonstrated and part of the session was devoted to training of new sales techniques, with a number of films shown. The meetings were conducted by R. T. Jones, Western regional sales manager, and L. J. Smith, Eastern regional sales manager.

NAC Advances Officers

National Aluminate Corporation, Chicago, recently announced the advancement of former assistant vice presidents H. R. Powers, Gage Averill and Alphonso Cantalini each to the post of vice president. Powers will be in charge of the chemical firm's industrial division sales, Averill in charge of catalyst division sales, and Cantalini will continue as European manager, headquartering in Rome, Italy.

Nuclear Power Valves Studied

Steel valve requirements for flow control of radioactive materials in nuclear power plants, which are being studied by laboratories of Edward Valves, Inc., were discussed at a week-long sales meeting. Sales engineers and representatives attending also visited the laboratories.

Dowell Expands

Plans for adding 12,600 sq ft of floor space in the Dowell research laboratory, in Tulsa, have been announced.

An additional 1450 square feet of floor space in the equipment assembly building is being prepared for the use of studying chemical batching and mixing of field size volume of materials.

Future programs include the addition of an electron miscroscope, X-ray fluorescence analyzer and a mass spectrometer.

Completion of this project will result in a substantial increase in the number of people engaged in research, company said. Personnel to be added later will be trained in chemistry, chemical engineering, petroleum engineering, physics, geology and related fields.

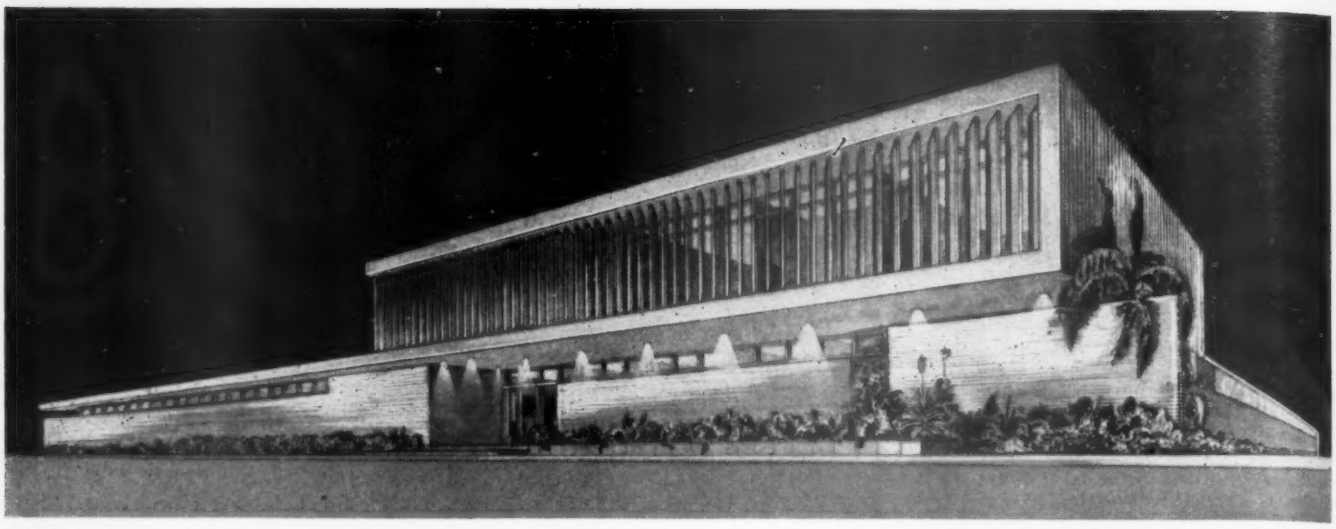
Plans for the new construction have been prepared by Frederick Vance Kershner.

New Home For Larkin Packer

The construction of a new plant and general office headquarters for the Larkin Packer Company, Inc., has been started in Waxahachie, Texas. The new plant will occupy a 28-acre site and will provide approximately 70,000 sq ft of completely modern shop and office space.

Lorum Outlet Named

Lorum Fibre Company, Inc., New York, has announced the appointment of Product Development Company of Houston, Texas, headed by Roy Dawson, as exclusive manufacturer's representative to the drilling mud industry in the United States (except for California) and Canada for the sale of Leather Fibre as a lost circulation additive. Leather Fibre is a patented product for well drilling developed in conjunction with the Research Laboratories of the Magnolia Petroleum Company, also sold under the trade names of Leather Floc and Leath-O.



PGAC Opens Main Plant, General Offices in Houston

April 23, 1955, represented another milestone in the colorful and fast-moving history of Perforating Guns Atlas Corporation, as it formally opened a new 10-acre plant at Scott Street and Holmes Road, in Houston, Texas. PGAC has outgrown two plants in the past five years, indicating its growth in logging and perforating services.

The new plant now comprises four buildings, providing over 26,000 sq ft of floor space. The office building is a two-story structure of modern design, which will be extended later as needed. It is directly connected to the research laboratories building. Here, research in radioactive developments for the oil industry will be carried on. Another building houses the shops in which are built PGAC's perforating guns, logging instruments and other equipment. The fourth building contains the garage and shops in which the company's trucks for field service are built and serviced.

Perforating Guns Atlas Corporation is affiliated with the National Cylinder Gas Company. And PGAC, in turn, has three affiliate foreign operating companies of its own: in Canada, Perforating Guns of Canada, Ltd.; in Germany, Deutsch-Amerikanische Olfelddienst, G.m.b.H.; and in Venezuela, Servicios Tecnicos Atlas, C.A.

Officers of PGAC are Paul Charrin, president; J. H. Castel, executive vice president and assistant secretary; J. W. Dunham, vice president; W. W. Whitnell, secretary; and L. Parker McKinley, treasurer.

On October 1, 1946, Charrin started the Atlas Research Corporation, which was destined later to become the present PGAC. The original company had the modest floor area for shop and office of only 500 sq ft—and one employee, Charrin! A few weeks later, Castel joined the embroyonic firm as vice president—the company's second employee.

Today, just 8½ years later, the company has over 430 employees working in four countries. It operates 35 stations, from which a fleet that now is fast approaching 100 logging and perforating field units serves the oil industry.

These two men, Charrin and Castel, were both born in France, and arrived in the U. S. A. in 1926 and 1938 respectively. Each immediately stuck his feet deep into Texas soil.

In 1947, the original Atlas Research Corporation changed its name to Atlas Well Service Corporation. The following year the company acquired the Perforating Guns Company, and in 1949 the two companies were merged under the present name, Perforating Guns Atlas Corporation. Prior to founding this enterprise, Charrin had resigned as executive vice president of the Schlumberger Well Surveying Corporation, with which firm he had been associated for twenty years.

Castel, prior to joining Charrin in 1946 in the enterprise that eventually was to become PGAC, was also with the Schlumberger Well Surveying Corporation. His resignation as vice president in charge of the perforating department terminated 20 years with that firm.

Dope Formula Changed

Silicones has been added to "Big 'D' Dope" manufactured by C. H. Dragert Company, Inc., Dallas, Texas. The innovation in the formula followed a survey of oil drilling engineers and maintenance executives in U. S. industry generally.

Baroid Expands in West Texas

Baroid Division, National Lead Company has expanded its service in the West Texas and Permian Basin area.

Baroid's present office in Midland has been made operational headquarters for the West Texas area, and S. D. Wiginton, Jr., has been appointed manager. Joe W. Beane has been appointed assistant manager. D. D. Varnell, sales representative, and Homer C. Leland has been appointed area engineer. Baroid's West Texas area is made up of four operational districts.

Litwin Company Formed

The Litwin Engineering Company, Wichita, Kansas, has been formed to design and construct refineries, gasoline, and petrochemical plants. Harry Litwin, president, was associated with Winkler-Koch and later was vice president of Koch Engineering Company.

Selas Builds Plant

Work has just started on a new $1,000,000 plant for the Selas Corporation of America, Philadelphia, which develops, designs, and manufactures microporus filters, membrane type separators, heaters and other fluid processing equipment for the chemical, petroleum, petrochemical and plastics industries. The new plant is being constructed on an eleven-acre site at Dresher, Pennsylvania.

New Sales Set-up

National sales of Springfield water-tube package generators will be made through the coast-to-coast network of Kewanee-Ross Boiler division sales offices. Kewanee-Ross Corporation, a division of the American Radiator and Standard Sanitary Corporation, maintains sales engineering offices in fifty-three cities with plants located in Kewanee, Illinois; Lebanon, Pennsylvania, and Buffalo, New York. The new name for the product will be the Kewanee-Springfield Water-tube Package Generator.

Gulf Steelwork Completed

Crews of the Consolidated Western Steel division of U. S. Steel Corporation recently completed erection of the steelwork for Gulf Oil Corporation's large new package and grease warehouse at Port Arthur. The big installation, covering some eight acres, required more than 1300 tons of structural steel. Located on the channel and adjoining Gulf's Port Arthur refinery, the warehouse will be 765 ft by 432 ft, for a total floor space of 330,480 sq ft.

H. M. Schudt Named President

Election of Harold M. Schudt as president, Canadian Allis-Chalmers Limited, has been announced by the Allis-Chalmers Manufacturing Company. The general machinery division of the parent Allis-Chalmers Company is in charge of operations of Canadian Allis-Chalmers Limited. In his new capacity Schudt will be in charge of operations which include general offices in Lachine, Quebec, manufacturing plants at Lachine and St. Thomas, Ontario, and sales offices in Montreal, Toronto, Winnipeg, Calgary and Vancouver.

Chrysler Expands

Chrysler Corporation's new "Forward Look" extends to the marine and industrial engine division, according to C. C. Williams, vice president, sales. In a recent address Williams outlined his division's new development and planning program.

He told his guests at a Los Angeles luncheon that the sales and service organizations of the Marine and Industrial Engine division are being expanded to give better coverage in important markets, and also announced the availability of the Chrysler industrial engine torque converter in two different models, with provision for tail shaft governors.

Fiberglas Marketed as Armaglas

The full line of Fiberglas industrial insulations made by the Owens-Corning Fiberglas Corporation will also be produced for the Armstrong Cork Company which will market them under the trade name, Armaglas. While basically the Armaglas products will be the same as those marketed by Owens-Corning, the firm has agreed to manufacture the Armaglas materials to Armstrong's specifications.

McMurry-Brown Organized

E. D. McMurry and Harold L. Brown have recently formed McMurry-Brown, Inc., an oil tool manufacturing and sales organization with headquarters in Houston. Initially, the firm is manufacturing a complete line of gas lifts, plunger lifts and surface controllers. Other items are now being developed and will be announced later. Sales and service points are being established at Oklahoma City, Hobbs, Odessa, Abilene, Tyler, Shreveport, Lafayette, Harvey, Victoria and Corpus Christi. Both men were vice presidents of Garrett Oil Tools before forming their present organization.

Dresser in Dallas Moves

Dallas, Texas, offices of the Dresser Industries, Inc., and Ideco, its drilling equipment division, have been moved from the Atlantic Building to the new Republic National Bank Building. Ideco offices are located on the thirty-first floor, and Dresser will install its new headquarters on the thirtieth floor.

Otis Office Opened

Otis Pressure Control, Inc., has opened a district office in Lindsey, Oklahoma, at 813 West Cherokee Place. Louis Payne and Raymond Fitzpatrick are in charge of the branch.

Employees Buy Core Lab

According to an announcement by John D. Wisenbaker, president, a group of Core Laboratories, Inc., employees recently completed the purchase of all remaining stock in the company formerly held by Case-Pomeroy, New York. The transaction marked the consumation of an option agreement made in 1950 when 51 per cent of Core Lab ownership was sold to members of the firm with the remaining interest being made available for purchase until 1962. Under the new ownership arrangement all operations will be under the jurisdiction of employees directly engaged in petroleum reservoir engineering activities.

Waukesha Branch Opened

Waukesha Sales and Service, Inc., has opened a new branch in Pampa, Texas, to provide better service for customers in the Texas Panhandle. Leon Miller is manager of the Pampa store and district manager of the Texas Panhandle area; John D. Pharr is parts manager at the store.

TOTCO Men End Meetings

Technical Oil Tool Corporation has announced the recent completion of the company's annual series of service meetings for TOTCO field representatives in the Mid-Continent area. These meetings were held in Houston, Oklahoma City and Odessa. The program was designed to acquaint the TOTCO field men with new practices and procedures of value to users of TOTCO instruments and equipment.

CRC Partnership Dissolved

Crutcher-Rolfs-Cummings, Inc., manufacturers and distributors of pipe line equipment and supplies, has announced the partnership that formed C. R. C. Engineering Company has been dissolved. H. E. Fisher, former director of C. R. C. Engineering Company is opening an office of his own under the name of Pipe Line Technologists in Houston and will continue in the same line of business formerly conducted by C. R. C. Engineering. Crutcher-Rolfs-Cummings, Inc. under the direction of A. S. Crutcher and Jim Cummings, will continue to deal exclusively in the manufacturing, sale, and rental of pipe line equipment.

Lone Star Holds Party

Lone Star Steel held its second annual Oil Party in May, consisting of a day's outing at its Lone Star, Texas, plant. Some 300 leaders in the petroleum industry saw how oil-country tubular goods are made from the ore through to the finished product.

A feature of the occasion was the naming of R. E. (Bob) Smith, Houston independent oil operator, as Chief Roughneck. E. B. Germany, president of Lone Star, presented Smith with a plaque and a lapel pin in recognition of rough and ready service in the field, and made him an honorary life member in the Roughneck's Club, a new organization to honor outstanding oilmen. The group is sponsored by Lone Star Steel.

Representatives Appointed

The Power Equipment Company, Memphis, Tennessee, has been appointed engineering representative in Western Tennessee, Northern Mississippi and Eastern Arkansas, for Childers Aluminum Weatherproof Jacketing. The product used for protection of insulated lines, vessels and towers is manufactured by the Childers Manufacturing Company of Houston, Texas. Bob Childers, president of the firm, said that the Power Equipment Company, started in 1941, will serve as engineering consultant and sales representative for the above area.

Rockwell Gives Field Service

Oil field installations and refineries, pipe lines, chemical plants and other users of Rockwell-Nordstrom plug valves can now contract for a comprehensive field lubrication and maintenance service under a plan announced by Rockwell Manufacturing Company's Meter and Valve division. The new service is designed to bring lubrication and maintenance service facilities right to "the door" of Rockwell-Nordstrom valve users by means of specially built trucks, the first units of which are already in the field.

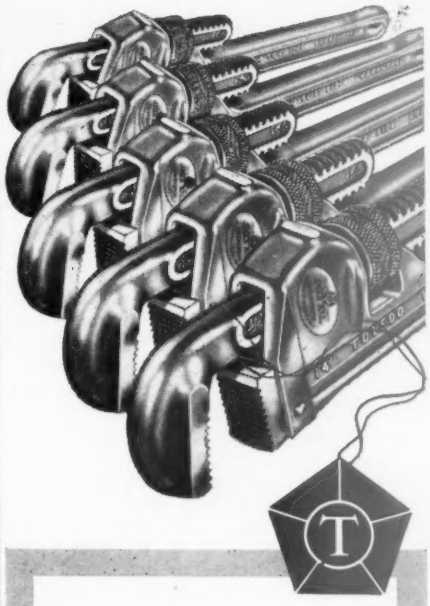
American Iron Sold

Negotiations have been completed resulting in the sale of all stock of American Iron and Machine Works Company of Oklahoma City to the American Machine and Foundry Company with headquarters in New York City.

Worthington Divisions Merge

The Wellsville Works and Steam Turbine sales division of Worthington Corporation, is being merged and will be known as the Steam Turbine division. Arthur F. Reinking, manager of the Steam Turibne Sales division for the past four years, has been appointed general manager of the new steam turbine division.

ASK THE ROUSTABOUT



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THE TOLEDO PIPE THREADING MACHINE COMPANY

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TOLEDO

PIPE THREADERS • PIPE WRENCHES • PIPE MACHINES

TRADE PERSONALS

Lee Kelton

J. H. Raidl

Jimmy Lee

Ralph Stevens

John Cross

John H. Raidl has been named as sales manager, West Coast district, of Black, Sivalls and Bryson, Inc. **Jimmy Lee** is district sales manager for BS&B's newly-created Salem Oilfield district. **Lee Kelton** has been appointed manager of Mid-Continent Oilfield sales and **Ralph Stevens** manager of Gulf Coast Oilfield sales. **Benjamin "Bill" Bourne** has been appointed Oilfield district sales manager for the Houston district. **John Cross** has been appointed Oilfield district sales manager for the newly-created Alice district.

G. M. Kernahan has been appointed sales manager of the Canadian division of McCullough Tool Company. Kernahan will continue to operate out of McCullough's Calgary office, directing and supervising sales operations in Western Canada. **Douglas McGuffin** has been appointed to the position of sales engineer in the Williston Basin area for the same company.

R. D. McClanahan has been named branch manager of the new service location at Baker, Montana, of McCullough Tool Company.

N. H. Ottinger has been appointed to the recently-created position of division logging engineer for McCullough Tool Company's Mountain division which covers Colorado, Montana, North and South Dakota, Utah, Wyoming and Nebraska.

Joseph C. Buerkle has resigned from C. Lee Cook Company to set up his own firm, the Joseph C. Buerkle Company. Offices are at 76 Broad Street, New York City. New company will represent C. Lee Cook in northwestern United States.

J. P. Murphy has been transferred from the Chicago sales office to the sales development unit of technical service and development of Dow Chemical Company to handle the sale of titanium.

R. E. TenHoor has been appointed supervisor of a new section of Dow, designated as the industrial chemicals section.

Ed Styron, a veteran of 20 years sales and practical experience in instruments and control engineering and the oil industry, has joined General Controls Company of Glendale, California, as a field representative.

Dr. Charles H. Kline is manager of the newly-created chemical development division of Climax Molybdenum Company.

Roy C. Ingersoll, president of Borg-Warner, has assumed the title of president and chairman of the board following action by the directors of the corporation.

D. M. Jacks and **Dr. W. H. Kirkpatrick** are new vice presidents of Visco Products Company, Inc.

Ralph D. Parker has been elected vice president, and **Walter A. McCadden,** comptroller, of The International Nickel Company of Canada, Limited.

U. V. Davis, Boston division credit manager of the Esso Standard Oil Company, has been elected president of the Association of Eastern Petroleum Credit Managers. Other officers and directors: **A. C. Cater, L. B. Morgan, E. A. Schramko,** vice presidents; **C. M. Mathewson,** reelected secretary-treasurer; **D. R. Meredith,** assistant secretary.

Elected to full terms on the board were **I. A. Keller,** and **W. S. Morris.** Elected for a two-year term on the board was **S. G. Steiner.**

Richard A. Geuder has been appointed assistant general sales manager of the Reliance Electric and Engineering Company and **Edward E. Helm,** the company's sales vice president, has been assigned the added duties of coordinator of all activities in merging the efforts of the recently acquired Reeves Pulley Company division with the other divisions of Reliance.

Jack N. Yetter has been named sales manager, general products division of Twin Disc Clutch Company.

Dr. Ernest H. Koepf has joined the administrative staff of Core Laboratories, Inc. as manager of the company's research and development department.

Lee A. Colbath, formerly an Edward valve sales engineer in the Chicago area, has been transferred to the W. E. Bowler Company, Edward representative in Philadelphia.

John C. Elmburg, formerly manager of the Fairbanks, Morse and Company's Portland, Oregon branch, has been named assistant general sales manager of the company effective July 1.

Carl L. Nickel has been named product sales manager, water systems and dealer line products, and **Norman C. Olson** product sales manager, engineered line products of Peerless Pump division Machinery and Chemical Corporation.

Harold R. Ashworth, salesman for northern Oklahoma with headquarters in Tulsa, has been assigned to Seminole, Oklahoma, as district manager for the Happy Company. He replaces **R. B. "Cotton" Rundle,** who has been promoted to city salesman in the Tulsa area.

Douglas McGuffin has been promoted to sales engineer in the Williston Basin area for McCullough Tool Company in Los Angeles.

John Thomas is assistant to Admiral **Wilson D. Leggett,** USN, ret., the company's new vice president of engineering, ALCO Products, Inc. Thomas will be located at ALCO's engineering headquarters in Schenectady.

John Van Wagoner has assumed new responsibilities in the advertising department of Wolverine Tube, Division of Calumet and Hecla, Inc.

R. C. Cash, sales representative for Wolverine Tube in Tennessee, Mississippi, Alabama and Eastern Arkansas, has moved his headquarters from Memphis, Tennessee, to Birmingham, Alabama.

C. P. Whitlock has been appointed sales representative in Philadelphia, of Calumet and Hecla, Inc. He replaces **John Van Wagoner.**

James B. Wilcox, executive vice president, and **Dante A. Siracusa,** vice president and sales manager of the S. R. Bowen Company left April 25 on an extended business trip through South America. Their itinerary includes Mexico, Panama, Guatemala, Colombia, Venezuela, Brazil, Argentina, Chile, Bolivia, Ecuador and Peru.

Robert J. Rice has been appointed sales manager for radioactivity well logging for the Gulf Coast division of Welex Jet Services.

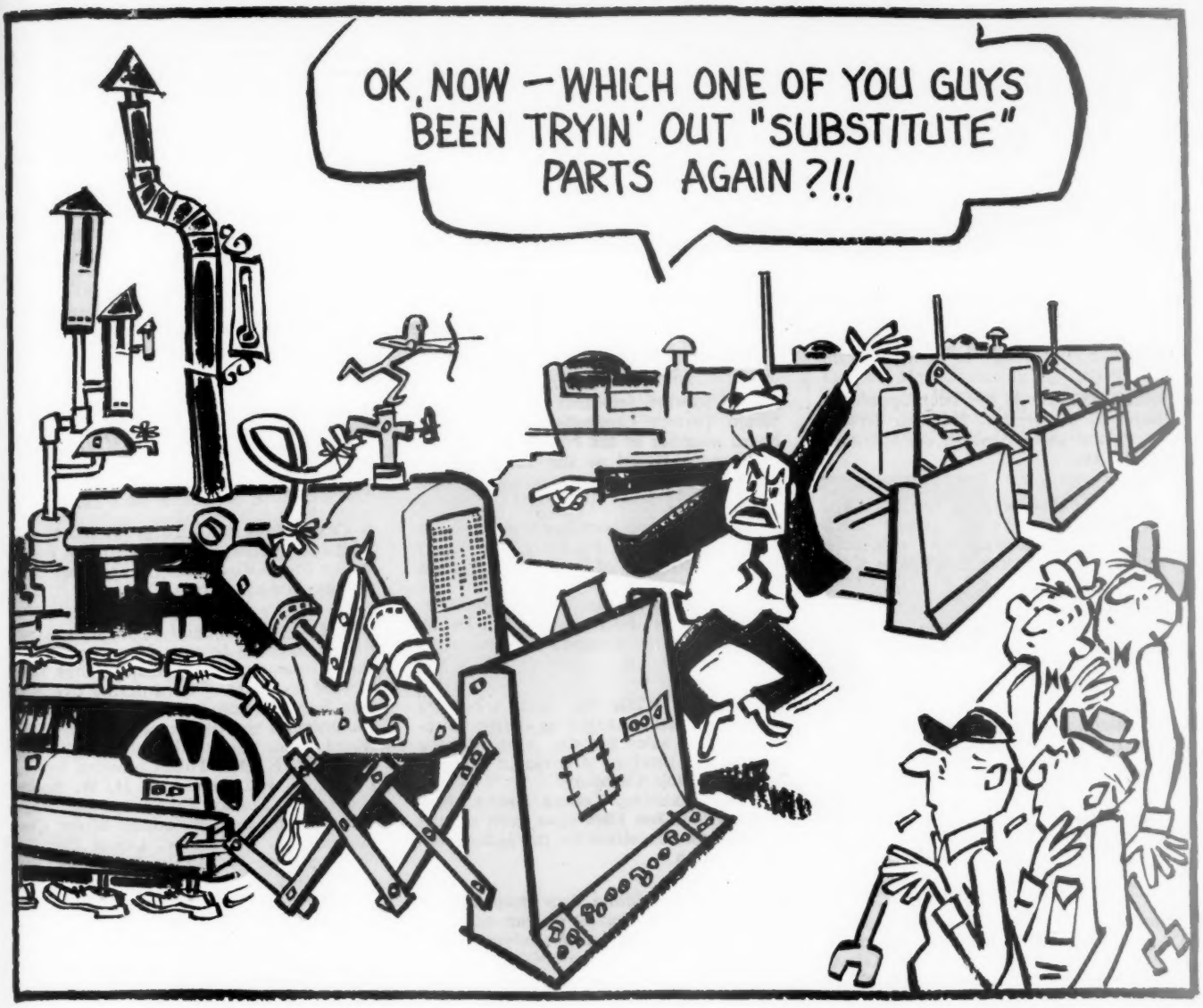
Richard C. Johanson has been named director of personnel and training of Continental Supply Company. He comes to Continental from Ford Motor Company.

Jack Yetter

Dr. E. H. Koepf

Robert Rice

R. C. Johanson



Down time is no joke. Best way to avoid it is to insist on genuine CAT* parts every time. Then you're sure of getting parts that are made to the latest design, precisely manufactured of the right materials, rigidly inspected and tested.

Take filters, for example

Non-genuine Caterpillar filter elements look like the real thing. They'll fit, too. They may even have plastic-impregnated elements — but how much surface area do they have? Look at the picture below. It shows what a genuine Cat surface-type filter is like *inside:* a plastic-impregnated paper element that does not absorb water, accordion pleated, for maximum surface area, around a perforated metal tube, enclosed in a perforated paper cover. This filter will *not* remove oil additives. It *will* remove abrasive particles as tiny as 39-millionths of an inch. A substitute filter — well, who can be sure?

The difference on the job: working in heavy dust, even in mud and water, genuine Cat filters — matched to the requirements of Caterpillar Diesel Engines — will keep these engines running longer, will keep maintenance costs low.

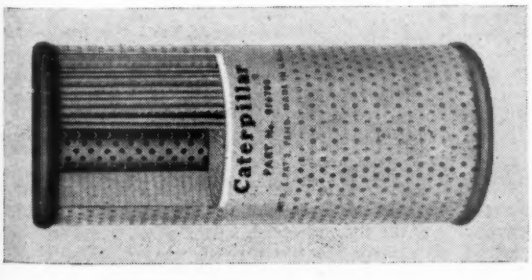
With substitute parts: who can be sure?

Better get genuine Caterpillar parts every time.

Caterpillar Tractor Co., Peoria, Illinois, U. S. A.

CATERPILLAR*

*Both Cat and Caterpillar are registered trademarks—®



Trade Personals

Hosts for open house at the new research headquarters, The Fluor Corporation, Whittier, California, were J. C. Fluor, president; W. R. Hainsworth, vice president, research; F. E. Fischer, secretary-treasurer; C. L. Blohm, manager research; M. A. Ellsworth, vice president and director of sales; J. R. Fluor, executive vice president.

John C. Scowcroft has been appointed manager of the product research department in the sales division of Sherman Products, Inc.

Charles E. Meluney, Jr., has been appointed Houston, Texas, district sales manager for the electrical wire and cable division of John A. Roebling's Sons Corporation.

W. Sidney Park, president of Park Aerial Surveys, Louisville, Kentucky, was elected president of the American Society of Photogrammetry at its 21st annual meeting in Washington, D. C. **William C. Cude,** chief of the topographic engineering department at the Engineering Research & Development Laboratories at Ft. Belvoir, Virginia, was chosen first vice president and **Kenneth E. Reynolds,** manager of the defense contracts department of Bausch & Lomb Optical Company, Rochester, New York, second vice president.

Thomas A. Collins has been elected vice president and assistant general manager of the newly-formed L.O.F. Glass Fibers Company. He is also a director of the company.

Francis H. May, Jr., is vice president, secretary and treasurer of the new company. **J. M. Johns** is vice president and director of sales. **Joseph S. Finger** is vice president and general manager of the Corrulux division. **Raymond W. Capaul** is vice president and sales manager of the general products division. **Clinton F. Hegg** is vice president and sales manager of the textile division. **Dominick Labino** is vice president in charge of glass research and new product development. **John A. Morgan** is vice president and general manager of the western division. **Jesse H. Plummer** is vice president in charge of manufacturing, engineering, and development.

Leon Hendrickson has joined Oil Base, Inc., as a sales engineer to service the Permian Basin. **Pete Petross,** who died recently in a highway accident near Odessa, Texas, formerly held the job.

Gene Towle, Apartado 7506, Mexico, D. F., has been appointed the sole Mexico representative for the entire line of Oil Base, Inc.

John Herbert Ahrens, assistant district engineer machinery and equipment sales and service, has transferred from Casper, Wyoming, to Ft. Morgan, Colorado, for U. S. Steel's Oil Well Supply division.

Harold S. Tipton, field representative for "Oilwell" has been transferred from McCamey, Texas, to Odessa, Texas.

Charles B. Dietrich has been named field representative at Ventura, California.

J. P. Stewart, president of the De Laval Steam Turbine Company, was elected a board member of the National Industrial Conference Board at the board's 156th meeting.

L. L. Fusby has been appointed production manager for Pacific Coast Borax Company, division of Borax Consolidated, Limited.

W. J. Diffley has been appointed superintendent of the Boron operations. **Dr. D. S. Taylor** has been appointed director of industrial research.

Arthur F. White has been appointed Detroit district manager in charge of direct factory sales for the Axelson lathe and milling machine division of Axelson Manufacturing Company.

Leroy Manning, Leland Kulzer, Roy Grigsby and **Joe Fitts** have been named factory representatives for the Mid-Continent division.

John M. Maitland has been named manager of the Detroit district office of The Bristol Company, Waterbury, Connecticut.

Ross B. Baze, has been named sales manager of Delta Tank Manufacturing Company's oil field equipment and special order products division.

Russell A. Gasal has been named general manager of Delta's Beardstown, Illinois, plant. **John T. Nesser** has been named sales manager of the firm's liquefied petroleum gas equipment division.

Dr. J. L. McCurdy has been promoted to assistant manager of The Dow Chemical Company's plastics production department. **Daniel W. Ryan** was promoted from production superintendent to manager of the Torrance, California, plant to succeed McCurdy.

Louis E. Tallman has been named head of the western section of Plastics Technical Service. **E. E. (Mike) Merrill** has been appointed to a new post as head of the eastern section of PTS. **Orwin G. Maxson** has been named to assist Tallman in the western section.

Richard H. Koehler has been appointed director of advertising and publicity for Westinghouse Air Brake Company.

W. C. (Bill) Talbert, Jr., has been appointed field service engineer for Mission Manufacturing Company.

Darrell Smith has been named manager of the Dallas, Texas, district office of Joy Manufacturing Company. He succeeded **J. A. Noyes,** retired.

Dr. Hyman Chessin has been appointed assistant director of research and development for the Van der Horst Corporation, Olean, New York.

F. E. "Jim" Farley has joined the sales staff of Master Tank & Welding Company, Dallas, Texas.

Raymond F. Keller, general manager of Canadian operations, has been appointed a vice president of General Geophysical Company.

William L. Davies has been named assistant to **Walter C. Robertson,** vice president of Gar Wood Industries, Inc., New York.

Kenneth A. DeLonge has been placed in charge of the iron and non-ferrous castings section of the development and research division of The International Nickel Company, Inc.

Craig Mays has been promoted to district sales manager in the Permian Basin, by the Baash-Ross Tool Company division of Joy Manufacturing Company.

B. G. Van Zee, chief engineer, automotive engineering division Minneapolis-Moline Company of Minneapolis has been elected president of the Internal Combustion Engine Institute, representing manufacturers in the high-speed gasoline and diesel engine fields. Other officers are: vice president, **E. Don Tull,** Cummins Engine Company, Inc.; secretary, **H. W. Smith,** Caterpillar Tractor Company, and treasurer, **Phil Norton,** Wisconsin Motor Corporation. **J. E. Heuser,** LeRoi division, Westinghouse Air Brake Company, was elected to the board of directors.

M. J. Ross has been named manager, export trade, for Quaker Rubber Corporation and The Watson-Stillman Company divisions of H. K. Porter Company, Inc.

Edmund K. Nock has been named superintendent of land sales of General Electric Company's Medium Steam Turbine, Generator and Gear department.

Michael E. Conway has been appointed advertising manager of Enterprise Engine and Machinery Company, subsidiary of General Metals Corporation. **Robert M. Pearson** is new field sales manager for the company.

J. D. Crell has been named sales engineer for the New York City Sales district of Graver Water Conditioning Company.

L. M. Keating and **T. H. Creden** have been elected directors of the A. O. Smith Corporation. Keating is Southwest regional manager and Creden is general sales manager for tubular products for the company.

H. L. Stockdale has been appointed to the presidency of the Insul-Mastic Corporation of America. He succeeds **Clifford Off.** Executive and sales offices have been moved to the plant office at Summit, Illinois.

E. O. Vetter is new vice president, administration, Geophysical Service Inc. He was formerly assistant vice president in charge of the administrative division of the Dallas geophysical contracting firm.

H. M. Thomas, has been named general superintendent of the new pipe mill of U. S. Steel's Consolidated Western Steel division. He has been assistant superintendent of construction since start of work on the project. **W. E. Fogerson,** who has been superintendent of construction, has been transferred to another of Consolidated Western's projects.

U. S. Steel's Oil Well Supply division, Garland, Texas, has **Robert F. Smalley** as manager, production, control and purchasing; **John R. Wilde** is manager of the Pampa, Texas, store; **Ivan R. Blauser, Jr.,** is assistant district engineer at Parkersburg, West Virginia; **Jack M. Lucey** is area manager, production equipment sales, of the Rocky Mountain area, and **John M. Rohrig** is new field representative at Huntington Beach, California.

Louis Q. Webber, plant manager of the Martin-Decker Corporation of Long Beach, California, is on a trip through the Middle East where he is visiting the active drilling areas in Saudi Arabia, Kuwait, Qatar, Iraq, and Egypt. He will probably return by way of Europe sometime in July.

E. L. Decker, president of the company sailed on the Liberte May 26 to attend the International Petroleum Congress in Rome.

A. H. Miller, vice president of Emsco Manufacturing Company has been named general manager of Johnston Pump Company which Emsco acquired on January 31.

The Continental Supply Company has announced the following changes in personnel. **Odus C. Tubbs** has been named district manager, Oklahoma district. **Tom H. Fraser** has assumed Tubbs' former position. **J. E. Gaman** is now North Texas district manager. **R. L. (Bob) Pebworth** is manager of a new West Texas district, with stores at San Angelo, Post, Snyder and Abilene.

Shepherd Stigman has been promoted to assistant director of personnel and public relations for Foster D. Snell, Inc.

James Corbett was named chemist-pathologist in the bacteriology and toxicology department. **Murray E. Ferencz** and **Morris Glazer** have been appointed chemists in the surface chemistry department. **Sidney Gottfried** is a chemist in the product development department and will specialize in paints and varnishes.

Walter H. Olin has been appointed sales representative in the Rocky Mountain area for Wolverine Tube, division of Calumet & Hecla, Inc.

Mel Jackson has been appointed sales representative in the northwestern part of Indiana and the south side of Chicago and immediately adjacent suburbs.

Edwin T. Goree has been appointed assistant sales manager, Excavator Distributors, for Bucyrus-Erie Company. Goree will assist **R. C. Adams** who was recently named sales manager of Bucyrus-Erie's widespread distributor, following promotion of **L. E. MacDonald** to general sales manager.

Werner G. Wassmandorf has been appointed to manage the reciprocating compressor sales department of The Trane Company. **Lloyd E. Eater** is manager of the fluid cooler sales department; and **Wilford R. Barnard** has been named head of the UniTrane sales department.

J. J. Coffey

J. W. McCormick

Pacific Pumps, Inc., Huntington Park, California, has opened a Philadelphia district office, with **J. J. Coffey** as district manager. The Philadelphia office is located at 1612 Market Street. **J. W. McCormick** has been appointed New York district manager of Pacific Pumps.

R. S. Durkee

W. D. Miller

Earl Englert has been appointed manager of catalyst sales for the gas processes division of The Girdler Company, a division of the National Cylinder Gas Company.

Appointment of **Lee S. Cline** as assistant vice president—production of U. S. Steel's Consolidated Western Steel division has been announced.

J. H. Loomis has been appointed manager of Worthington Corporation's St. Louis office. Previously, he was general line salesman and compressor specialist at the company's Chicago district office.

John W. Tucker has joined the field sales staff of Cummins Engine Company, Inc., as a regional representative, with headquarters in Los Angeles, California. **Loyd E. Williams** has been named manager-distribution, for the company.

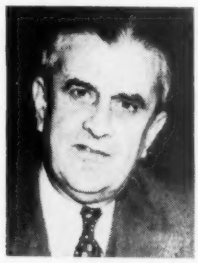
Roger W. Robinson has been appointed sales manager for Clark Equipment Company's transmission division. He will make his headquarters at the company's transmission plant in Jackson, Michigan.

U. S. Steel Corporation announces the following appointments: **Burley N. Pedigo** as field representative at New Iberia, Louisiana; **James Anthony Groves** as field representative at Swift Current, Saskatchewan, Canada; **Joseph Harry Young** as field representative at Virden, Manitoba, Canada; **Victor H. Blott** as store manager for "Oilwell" at Victoria, Texas; **Calvin Reed McAffee** as store manager of Huntington Beach, California; **John S. Purvis** to the Gulf Coast area organization; **William E. Lennard** as city representative, Los Angeles, California; **R. P. Mitchell** as field representative at Albany, Texas, and transfer of **Elmer E. Stanley,** field representative for U. S. Steel's Oil Well Supply division, from Duncan, Oklahoma, to Healdton, Oklahoma.

H. S. (Bud) Schuler has joined the Beckman division of Beckman Instruments, Inc., Fullerton, California, as advertising and sales promotion manager.

James L. Emerson has been named to fill the newly-created post of assistant to the manager of Chiksan Company's sales development department under **E. N. Thomas. Albert E. "Dutch" Plomp** has joined Chiksan of Canada Ltd. as a senior salesman.

H. P. Boncher and **W. D. Miller** are new operating vice presidents of Dresser Industries. Boncher will be succeeded in his position as general manager of Dresser Manufacturing division by **F. G. Fabian, Jr. Rodney S. Durkee** is a new member of board of directors and executive committee of Dresser Industries.



H. P. Boncher

F. G. Fabian, Jr.

James H. Curtis has been elected vice president of The Lummus Company. He was formerly assistant to the president. **D. R. Breien,** company treasurer, was elected secretary and treasurer; **Mario J. Marchione,** assistant treasurer was elected assistant secretary and assistant treasurer; and **Theodore F. Brophy,** company counsel, was made assistant secretary.

Bob Willis, Sr., president of the Willis Oil Tool and Creighton Oil Tool companies, is on a South American tour to set up distributorships for Willis chokes and fluid control valves.

Bob Willis, Sr.

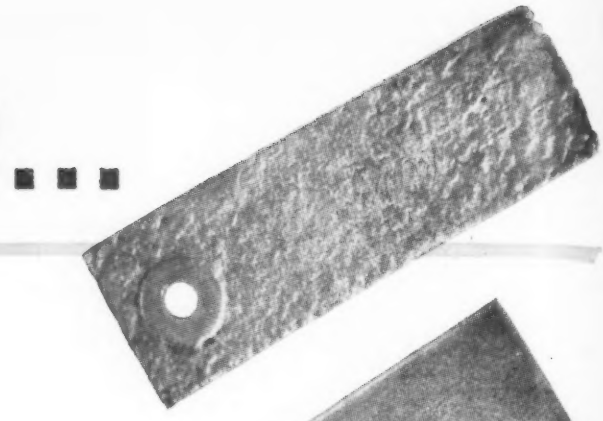
Don Vandenberg

Don Vanderberg, sales manager of Fluid Packed Pump Company is making an extended trip through South America in the interest of Oilmaster Pump Specialties. Vandenberg will meet with Fluid Packed Pump Company Exporting Distributors, The Natural Supply Company of Venezuela, confer with their personnel and visit oil fields and field stores.

Robert Duff Clark has joined Page Oil Tools, Inc., as chief engineer in its Long Beach, California plant.

Roy Woodside has been appointed vice president of Dunham Tanks in charge of the Texas Gulf Coast division.

before...



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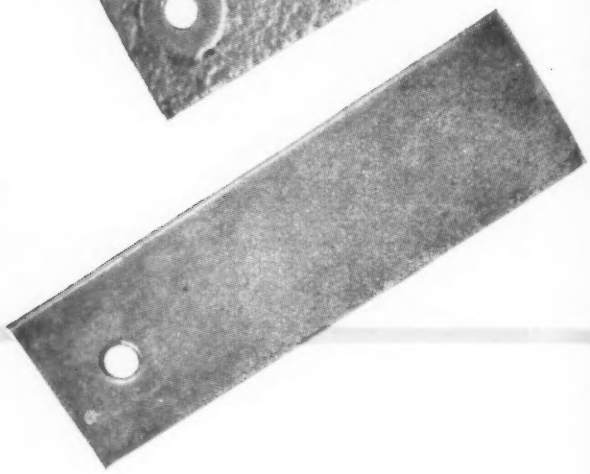

with *Visco* corrosion control!

HERE are several sets of typical before and after coupon test figures in wells now getting Visco Anti-Corrosion Treatment. Estimate the *tons* of well equipment metal saved by Visco Treatment, and you get an idea of the *dollars* saved in labor and replacement costs . . .

Well	Maximum Weight Loss—Mils/year	
	Before Visco	With Visco
1.	11.00*	0.02
2.	4.90	0.40
3.	8.10*	0.86
4.	7.50	0.08
5.	16.00*	1.30

** These wells receiving "anti-corrosion" treatment. Replaced by Visco.*

1 mil = .001 inch. A corrosion rate of 216 mils per year means that the corrosive attack, if uniform, would have corroded away the entire surface of the metal to a depth of .216 inches in a year. However, the real danger of high corrosion rates, as the coupon shows, is the much deeper and faster penetration occurring at localized areas.

These are not super-success figures. Chances are high that Visco can equal or better these results in *your* wells. Phone, Houston, MAdison 0433, collect, or write for positive Visco action today.

VISCO PRODUCTS COMPANY
Incorporated
2600 Nottingham at Kirby • Houston 5, Texas

Visco® ... CONSISTENTLY EFFICIENT OIL FIELD CHEMICALS

NEW oil and gas Equipment

- Machinery
- Supplies
- Services

For more information on items described here in brief, use the handy reply card and circle the corresponding numbers

(1) POWER UNITS

International Harvester Company introduces its U-282 carbureted power unit which runs on either gasoline or natural gas. The six-cylinder, valve-in-head engine has a 6.5 to 1 compression ratio. Construction includes counter-balanced crankshaft, four precision, replaceable bearings, T-slot aluminum alloy pistons, heavy industrial flywheel and torsional vibration damper. Exhaust valves are rotated slowly so they seat at different points on the valve seat insert.

Circle number (1) on reply card.

(2) WORM GEAR REDUCER

Philadelphia Gear Works has produced Steeple Type Worm Gear Reducer for long unsupported vertical output shaft extrusions which it claims has been successfully used in a wide variety of applications. The "Steeple Feature" can be mounted on standard types of Philadelphia Vertical Worm Gear Units without major modifications to the basic gear unit.

Circle number (2) on reply card.

(3) MICROWAVE EQUIPMENT

Raytheon Manufacturing Company has developed two-way microwave communications equipment, Raytheon TCR-12A, for the pipe line industry. Emphasis is on mobility and adaptability for changes in pipe line distribution systems for both permanent and temporary type installation.

Circle number (3) on reply card.

(4) ELECTRONIC TESTER

Simpson Electric Company is marketing a portable temperature tester with readings from —50 F through 1000 F. This electronic tester called the "Therm-O-Meter," is designed to measure gases, solutions, or solids on one 7-in. scale.

Circle number (4) on reply card.

(5) ANGLE COMPRESSOR

Pennsylvania Pump and Compressor Company is marketing a duplex compressor designated Class HAE, two-stage, heavy-duty, water-cooled, angle type machine. Its outstanding features include: compact, portable, streamlined; flexibility of installation; air-cushion valves, and full pressure lubrication.

Circle number (5) on reply card.

(6) PORTABLE RIG

Special portable rigs have been developed by Exploration Equipment Company. Model 50 can be used for seismographic exploration for depths under 100 ft and is provided with a special cat haul to permit power lifting of Kelly tools and drill pipes. It is powered by a K160 engine manufactured by Kohler Company.

Circle number (6) on reply card.

(7) UTILITY CRANE

Link-Belt Speeder Corporation has introduced a self-propelled, one-man operated, rubber-tired utility crane which it says offers unique advantages previously unknown to utility cranes. Designated as the UC-68, with 15-tons lifting capacity, it is designed for mobile work in such installations as public utility plants, refineries, and related fields.

Circle number (7) on reply card.

(8) CHEMICAL PROCESS PUMPS

The Duriron Company introduces Series H Durcopumps, a line of heavy duty chemical process pumps designed for continuous operation. These pumps are built for high heads and low capacities as well as routine transfer services. Durcopumps are said to be simple, sturdy, and versatile.

Circle number (8) on reply card.

(9) INSTRUMENT HARNESS

Dekoron Products division of Samuel Moore and Company presents a corrosion-proof, multiple-line intrument harness of "ribbon" construction called Dekoron "M" Ribbon. It is in production and available for short term delivery. Construction enables one or more individual tubes, or group of tubes, to be stripped from the ribbon without tools and without destroying the protective coating.

Circle number (9) on reply card.

(10) LIQUID GAGE

A new, heavy duty magnetic liquid level gage, the Criterion, designed for the LP gas and anhydrous ammonia industry, is announced by Rochester Manufacturing Company. Simple modifications of the Criterion LP gas gage make them available for ICC vertical cylinders, horizontal cylindrical tanks and spheres, for above or below ground service.

Criterion snap-on dials are the same size for both junior and senior models. Dials are hermetically sealed.

Circle number (10) on reply card.

(11) CONTROL UNIT

A remote monitor and control unit for unattended pump stations is being produced by Nelson Electric Manufacturing Company. Unit provides a method whereby a pipe line dispatcher, by use of existing telephone facilities, may make audible contact with a pumping station to determine the operating status of the pumping unit. By use of the monitor and control unit the dispatcher may also start or stop the pump motor. The unit can be installed on present telephone lines and may be used for up to 125 stations on one pair of telephone lines.

Circle number (11) on reply card.

(12) TWO-WAY RADIO

A standard super-power two-way radio unit for extended communication range has been developed by the General Electric Company. The radio is said to be capable of transmitting up to a 110-watt signal.

Circle number (12) on reply card.

(13) TUBING BLOCK HOOK

Guiberson Corporation presents a streamlined, unitized tubing block and hook combination that it says falls fast, will not foul up and carries loads in perfect balance. This block and hook combination is within API specifications on *every* count. Heavy duty anti-friction bearings with individual lubrication are used throughout. Approximate weight is 2730 lb or 2280 lb with cast steel sheaves.

Circle number (13) on reply card.

(14) DIAMOND BITS

A new line of diamond coring bits has been announced by Hycalog, Inc. Bits afford exceptional fluid relief and increased rate of penetration. Manufactured in a new division of the Hycalog plant, the bits are available in a variety of models and sizes to meet the requirements of any diamond coring program.

Circle number (14) on reply card.

(15) MILLIVOLT INDICATOR

Beckman and Whitley, Inc., has seven ranges, covering values from 0.25 to 25 millivolts in a new portable indicating instrument. Combination of laboratory precision with ruggedness has been the objective of this unit. Specific uses include those associated with thermal radiometers, heat-flow transducers, surface-temperature explorations, and the checking of recording potentiometers.

Circle number (15) on reply card.

(16) GENERATORS

Girdler introduces generators to produce hydrogen sulfide for metallurgical and other uses from hydrogen and sulfur. Process comprises continuous reaction of hydrogen with sulfur at elevated temperature and pressure, recovery of the heat of reaction by heat exchange, and final sulfur removal from the hydrogen sulfide by cooling to the point that sulfur vapors are frozen out in alternating exchangers.

Circle number (16) on reply card.

(17) ALLOY WIRES

A new line of tubular fabricated alloy wires for open arc application through standard semi-automatic welders is announced by Stoody Company. Depositing 7 to 15 lb of hard metal an hour, this "material-and-method" combination makes a welding speed two or three times that of the manual process possible.

Circle number (17) on reply card.

(18) DRY CEMENT TRANSFER

Halliburton Oil Well Cementing Company is using Worthington air compressors to transfer dry cement from trailer-mounted tanks to mixers for cementing oil wells. The compressor is mounted behind the cab of a semi-trailer truck and driven by V-belts from a power take-off. These truck-mounted units are sent to various parts of the United States where Halliburton has oil field service facilities.

Circle number (18) on reply card.

(19) DROTT MATERIAL handling rack lifts an 8000-lb International TD-6 crawler. Rack is mounted on International TD-18A.

Circle number (19) on reply card.

(20) BOTTOM HOLE PLUG

The Cavins Company has introduced an improved bottom hole indicating plug. Its purpose is to give an immediate and definite indication to the well clean-out crew that the well bottom has been reached. Of a cement-like material impregnated with a bright yellow pigment, it is easily distinguishable from the material that is being cleaned out.

Circle number (20) on reply card.

(21) ELECTRIC MOTORS

Louis Allis Company has ready a simplified motor stocking with the new L. A. line of electric explosion-proof motors. Underwriters' approval has been received for these units. Stocking problems are greatly reduced because a single motor can be used for most hazardous locations, company says.

Circle number (21) on reply card.

(22) EXHAUST SILENCER

Burgess-Manning has developed a new line of acoustic discharge silencers with a snubbing principle designed to eliminate high and low frequency noises caused from gas, steam and air operated equipment. These silencers mount on the exhaust of steam vents, gas turbines, hogging jets, evacuating ejectors, etc., and reduce the sharp, noise producing impulses of discharging gases to an even, constant noiseless flow. A complete range of models will be offered in standard 8 to 30 in. pipe sizes. Special sizes may be engineered to specific applications.

Circle number (22) on reply card.

(23) ENGINE CONTROL UNIT

Amot Controls Corporation announces Amot Model 1476-47 safety control made to shut down any internal combustion engine on high jacket water temperature or low lubricating oil pressure. The control has a built-in valve which is tripped by high water temperature or low oil pressure. On liquid fuel engines, the control will shut off the fuel supply when tripped. On natural gas engines, the control is used for operating a pneumatically operated gas shut-off valve. One feature of the Amot control is that ordinary copper tubing can be used, thus making repairs easy.

Circle number (23) on reply card.

(24) MAGNETIC STARTER

A new NEMA size 4 vertical lift magnetic starter, 40 per cent smaller than previous models of the same size, has been announced by the General Electric Company's general purpose control department. Designed for motors of up to 100-hp rating, the new starter is the same size and has the same mounting dimensions as the size 3 model, according to company engineers.

Circle number (24) on reply card.

(25) PLASTIC TUBES

Crane Packing Company introduces a plastic lead seal polyvinyl tube which provides an easy method for applying the compound to threaded connections and other surfaces to eliminate waste. Tube is made from tough polyvinyl plastic which company says will not crack at the seams or separate at the bottom crimp.

Circle number (25) on reply card.

(26) SPRAYING DEVICE

Spang-Chalfant division of The National Supply Company has introduced spraying machinery developed to apply

plastic quickly and evenly inside drill pipe and oil well tubing, and gas-fired ovens in which the coating is baked on the pipe. Each tube is given 8 passes by the spray lances, and is baked after each pass. Two coats of plastic are applied at each pass.

Circle number (26) on reply card.

(27) MOTOR PUMPS

Westinghouse Electric Corporation introduces hermetically sealed motor-pumps that will handle radioactive water with zero leakage in capacities from 5 to 17,000 gpm. These pumps are said to provide a convenient means of pumping water—and many other fluids—at system pressures up to 2500 psi and temperatures as high as 650 F. Special designs are available for handling liquid metal at even higher temperatures and higher pressures.

Circle number (27) on reply card.

(28) CLEARING UNIT

Homelite Corporation announces a low-cost attachment to convert its Model 17 chain saw into an all-purpose clearing unit. The clearing attachment is said to be ideal for use by pipe line companies. Simple to operate it permits one man to do the work of a whole gang.

Circle number (28) on reply card.

(29) WATER PURIFIER

Rogers Geophysical Company announces its water purifier for foreign field crews. In isolated locations, pure drinking water is always a problem. With this equipment Rogers crews can now convert river, pond or salt water into drinkable water at the rate of 48 gal per hour.

Circle number (29) on reply card.

(30) PIPE LINE SAMPLER

A new automatic pipe line sampler designed for extracting more accurate line samples of crude oil, fuel oil, gasoline and most other liquids has been announced by Gilbert & Barker Manufacturing Company. The sampler extracts many minute samples (300 per minute if desired), thus the composite accumulated is representative of the constituent flow. The Gilbarco sampler can be supplied with control proportional either to time or to flow. Pressure up to 350 psi and temperatures to 200 F can be handled by standard models. Special models are available for higher pressures and 350 F.

Circle number (30) on reply card.

(31) CENTRIFUGE

A new model, hand-driven centrifuge for determining basic sediment and water in crude oil has been announced by W. H. Curtin & Company. Known as the Series 53, the new centrifuge incorporates many new features, including a weight reduction of approximately one-third. Curtin engineers say the new machine meets a long-felt need of gagers for a lightweight, heavy-duty type machine for field use.

Circle number (31) on reply card.

(32) DRILLING MUD

The Crossett Chemical Company has recently marketed a Seeco-Mul drilling mud emulsifying agent which company officials say has reduced mud costs and rig time by as much as one-half over ordinary muds. Seeco-Mul is a dry, powdered compound of abietic, linoleic, and oleic acids, wood tannins, and lignins.

Circle number (32) on reply card.

(33) GOOSENECK TRAILER

A "powerized" gooseneck trailer that can be loaded or unloaded by one man, without skids, has been announced by LaCrosse Trailer Corporation. Designed especially for moving heavy loads in congested areas, or where low overhead clearance is a problem, the new trailer combines low carrying height with an arrangement that permits disconnecting the gooseneck automatically from the rest of the trailer.

Circle number (33) on reply card.

(34) NELSON MOTOR STARTER

An oil well pumping control unit has been introduced by the Nelson Electric Manufacturing Company. The unit incorporates many exclusive features such as a plug-in time switch, plug-in undervoltage relay, plug-in undervoltage relay with sequence starting, plug-in start-stop push button station and space for a meter socket or test device.

Circle number (34) on reply card.

(35) VOLT-AMMETER

A lightweight, pocket-size clamp volt-ammeter, with a single, easily read scale for all ranges and functions, and employing a special shock-mounted instrument movement, has been introduced by the Weston Electrical Instrument Corporation. Known as model 749, this instrument incorporates the Weston CORMAGR self-shielded mechanism with spring-backed jewels.

Circle number (35) on reply card.

(36) NEOCOR SERIES

The Corrosion Control Company, Inc., has introduced a new line of chemical-resistant coatings and linings for plant maintenance. Called NEOCOR C-10 and NEOCOR HD Series, both neoprene-based series are said to be effective protection against many corrosive reagents as well as over a wide temperature range.

Circle number (36) on reply card.

(37) GAGE LIGHTING

Liquid level page lighting with redesigned and improved gage illuminators have been announced by Jerguson Gage & Valve Company. These illuminators are designed to give an even diffusion of light over the entire length of the gage glass with no glare spots or blinding areas.

Circle number (37) on reply card.

(38) TRANSFORMER

A new five-kv current transformer (Type SM-5) molded in silicone is available from the Westinghouse Electric Corporation. Designed for indoor metering and relaying applications it is built in standard current ratings from 10 to 800 amperes. The transformer has a rating factor of 1.5 and is in the 0.3 accuracy class for all metering burdens. It meets all ASA and NEMA standards.

Circle number (38) on reply card.

(39) DUO-PLY WINDINGS

Duo-ply roll windings, which allow increased production, have been added to the line of Du Pont's Seismo-Writ, Lino-Writ, and high speed Lino-Writ photo recording papers, the company's photo products department has announced. Used for making two copies of oscillographic traces with a single exposure, Du Pont duo-ply rolls consist of extra thin, ledger-weight surface "W" paper interwound with standard document weight surface "B."

Circle number (39) on reply card.

(40) HYDROMETER CASE

A new spark-proof triple hydometer case weighing less than 1½ lb is being offered by W. L. Walker Company. Made entirely of welded sheet aluminum, the case is 40 per cent lighter than previous models. Hydrometers lie below the top edge of these cases and are protected with wool felt lining. The case is equipped with a Walker Safety Latch.

Circle number (40) on reply card.

(41) M-3 GUNS, BULLETS

McCullough Tool Company has developed a new deeper penetrating Ogival Bullet; a redesigned, more effective pressure seal; and further refinements in the firing chamber design of its M-3 bullet perforators. The improved M-3 Guns firing the bullets have shown an increase in penetrating ability of 50 to 75 per cent over results previously obtained.

Circle number (41) on reply card.

(42) DIESEL CRAWLER

Allis-Chalmers has announced its second new crawler tractor this year, the 31,500 lb HD-16, available with torque converter drive and standard transmission. This model follows the 44,000 lb HD-21 tractor and the TS-360 motor scraper announced earlier. The HD-16 has the new Allis-Chalmers 6-cylinder, 844 cu in. diesel engine that develops 150 net engine hp at 1800 rpm with torque converter and 140 net engine hp at 1600 rpm with standard transmission.

Circle number (42) on reply card.

(43) TANK GAGE

A fully automatic tank gage that provides increased gaging accuracy has been announced by Shand & Jurs Company. Designated by S&J as Fig. ST-8000, this new gage incorporates a Neg'ator motor replacing the counterweight and cable assembly. It is reported that the use of the Neg'ator motor materially reduces friction, compensates for tape pay-out and reeling in, maintains constant tape tension, and is ideally suited for greater accuracy throughout long float travel in tanks up to 65 ft in height.

Circle number (43) on reply card.

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FE-56

New Equipment

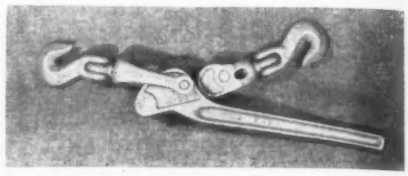
(44) POWER ENGINES

Worthington Corporation has announced a new line of power engines. The new engines, known as the SW 14 line, are a high pressure turbo-supercharged, four cycle design, rated from 1360 to 5000 hp at 450 rpm. Largest of the new line is a 16-cylinder V-engine said to develop twice as much power as present diesels of the same weight and dimensions.

Circle number (44) on reply card.

(45) LOADBINDER

Texas Foundries has announced a new series of E-Z PULL loadbinders featuring a patented cam action. Pull-down to lock position is so easy that cheater bars are usually unnecessary, and dangerous handle snap-down is eliminated. Cam action elimi-



nates slack-off when handle is pulled down and locked. Patented design also permits use of loadbinder around curves or square corners without slack-off. Safety features include elimination of dangerous kick-back when handle is released. Available in 12 different models.

Circle number (45) on reply card.

(46) BRONZE VALVE

A bronze globe valve, the LQ600, has been introduced by The Lunkenheimer Company. In the past four years leading companies have cooperated in tests by installing LQ600 valves on their most difficult "problem installations." During the testing program, the LQ600 valve is said to have never failed or leaked—even in installations where other valves had been replaced regularly from month to month.

Circle number (46) on reply card.

(47) AIR-COMPRESSOR

Schramm, Inc., is offering a self-propelled air compressor known as the Standard Pneumatractor. Schramm has used the same 125 cfm engine-compressor power plant as used in the heavy Pneumatractor, and in the 125 cfm Pneumapower portable compressor in building the self-propelled tractor unit.

Circle number (47) on reply card.

(48) ELECTRIC PLANTS

A line of small engine-driven generating plants ranging in size from 500 to 2500 watts has been announced by D. W. Onan & Sons Inc. Entirely Onon-built. these new air-cooled, gasoline-operated electric plants are designed to provide greater output at less weight and for lower cost. The heavy-duty, 4-cycle engine was designed specifically for long-life generating plant service.

Circle number (48) on reply card.

(49) ROTARY 600 PORTABLE

A rotary portable air compressor, which is said to combine the basic rotary advantages with the advantages of water cooling, has been announced by Gardner-Denver Company. The compressor has a capacity of 600 cu ft per min., and is considered especially suitable for air drilling with rotary drilling rigs.

Circle number (49) on reply card.

NEW oil and gas Literature

- **Brochures**
- **Bulletins**
- **Catalogs**

For more information on items described here in brief, use the handy reply card and circle the corresponding numbers

(50) ALUMINUM

The process industry applications of aluminum for producing everything from beer to bomb shells are analyzed in a new 80-page book by Aluminum Company of America.

"Process Industries Applications of Alcoa Aluminum" describes process applications of aluminum by industry and product, gives a comprehensive directory of performance of aluminum with various chemicals, and offers tips on designing aluminum processing equipment.

Circle number (50) on reply card.

(51) GENERAL CATALOG

Dowell has issued a 24-page general catalog in 2 colors presenting its entire products and service line. The booklet is fully illustrated and contains a section on research as it relates to development of scientific methods.

Circle number (51) on reply card.

(52) POWER UNITS

Climax Engine & Pump Manufacturing Company has issued a 12-page bulletin, No. SA-611, on Climax Blue Streak special power units for gas compressors.

The bulletin gives detailed information on Climax models K-67, K-75, V-80, V-85, V-122, and V-125.

Circle number (52) on reply card.

(53) FIRE SUITS

Two articles of apparel for fire fighters are described in a bulletin just published by Mine Safety Appliances Company.

The MSA Approach Type Fire Protection Suit is made of a fiber glass fabric specially woven for additional tear-strength and abrasion-resistance. Hood is a separate unit for face, head, shoulders.

Circle number (53) on reply card.

(54) ELECTRIC UNITS

Latest issue of Power Points Digest, company publication of D. W. Onan & Sons, Inc., is devoted to application of Onan Marine electric plants and generators.

Circle number (54) on reply card.

(55) AUDIO AMPLIFIER

Bulletin describing type FG-5- or 10-kw variable frequency audio amplifier is released by Westinghouse Electric Corporation. Applications of the amplifier are suggested. Design and construction features are discussed, and operation is described.

Circle number (55) on reply card.

(56) LIMA EQUIPMENT

Baldwin-Lima-Hamilton Corporation, Construction Equipment divison, announces revised descriptive bulletins covering the LIMA Type 34 and 44 power shovels, cranes, draglines and pull shovels on crawler and wheel mounts.

Circle number (56) on reply card.

(57) MOTORPUMPS

Motorpump Bulletin, Form 7093-E, has been released by Ingersoll-Rand. It covers company's line of close-coupled Motorpumps from ¼ to 75 hp for delivery of 5 to 2800 gal per min.

The bulletin is designed to make easy selection of correct size and model. A visual and concise index shows basic classifications of pumps.

Circle number (57) on reply card.

(58) FORGINGS

Ladish brochure demonstrates how designers can utilize advantages of closed-impression drop forgings for intricately shaped parts as large as 10,000 lb to provide maximum dynamic strength and toughness, reduce dead weight, cut machining time and costs and improve product design for safety and dependability.

Circle number (58) on reply card.

(59) DIESEL ENGINE

Ingersoll-Rand, announces a new 20-page bulletin describing its "S" and "SS" heavy duty diesel engines in sizes from 375 to 1000 hp. Bulletin provides information about lubrication, cooling and fuel injection systems of the engines and furnishes details about housing design, full floating aluminum bearings, large diameter crankshaft, gear driven auxiliaries and other features.

Circle number (59) on reply card.

(60) SYNTHETIC AMMONIA

How high yields, low operating costs, and flexibility of plant design can be obtained in the production of synthetic ammonia is the subject of a new 12-page booklet published by Chemical Process division of The M. W. Kellogg Company. It describes the four basic plant types offered for generation of synthesis gas tailored to suit local conditions and types of feed materials.

Circle number (60) on reply card.

(61) FILTRATION

Fundamentals of Filtration are described in a new bulletin by Engine Life Products Corporation. The attractive 8-pager covers gasoline, diesel fuel, butane and propane, natural gas, crude oil and residuals.

Circle number (61) on reply card.

(62) SPEED CONTROL

"Automation Through Varitrol Control," is the subject of a new full-color 8-page booklet by U. S. Electrical Motors Inc. Book illustrates how an improved pneumatic control, Varitrol, has been designed into U. S. Varidrive Motors to increase and/or improve output of a customer's product, reduce waste, save time and man power.

Circle number (62) on reply card.

(63) FILTERS

The Hilliard Corporation describes its *portable* line of HILCO Hyflow Oil Filters in four-page-buletin 316. Bulletin discusses oil maintenance ability of HILCO Hyflow Oil Filters and lists uses.

Circle number (63) on reply card.

(64) OIL'S VITAL ROLE

An article, "Straight Down to Modern Times" is featured in the latest issue of Production Road magazine released by Twin Disc Clutch Company. Article describes the vital part oil plays in every industry and in every phase of industry.

Circle number (64) on reply card.

(65) PUMPING CONTROL

An improved oil well pumping control which incorporates all field-tested features has been announced by Cutler-Hammer, Inc. Features incorporate provisions for changing restarting characteristics in the field.

Circle number (65) on reply card.

(66) DIAMOND PRODUCTS

Industrial Diamond Products Company has issued a new catalog, "Diamonds for Industrial Applications," describing its complete line of equipment, together with illustrations, drawings and tables. Booklet also covers company's diamond abrasive products.

Circle number (66) on reply card.

(67) PLUG VALVES

Its line of newly-designed lubricated plug valves are described by Ohio Injector Company in a bulletin just off the press. Information includes specifications, service recommendations and functions of the new plug valves.

Circle number (67) on reply card.

(68) ROD LUBRICATOR

A four-page brochure by Drovil Company describes its polished rod lubricator, tells how to install it, and offers a price list and specifications.

Circle number (68) on reply card.

(69) HYDRAULIC DRIVES

An 8-page 2-color brochure by Berry division, Oliver Iron and Steel Corporation, is called, "Berry Hydraulic Drives for Aerial Cooler Fans," and lists advantages, circuit diagrams, design and construction features and versatility of the product.

Circle number (69) on reply card.

(70) TRACTOR LOADERS

A booklet describing the Sherman front end loader for Fordson major diesel tractors is offered by Sherman Products. Two models are described and illustrated.

Circle number (70) on reply card.

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Long Extra-Leverage Handle with "line locking" feature.

Case-hardened Frame for longer wear.

Solid Brass 20-ounce Plumb Bob penetrates heavy oils.

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Trade Literature

(71) PLASTICS

Atlas Mineral Products Company has released an 8-page bulletin on rigid plastic fabrications and pipe. Bulletin outlines use of Type 1 polyvinyl chloride in the fabrication of exhaust systems, process equipment, and processing tanks. Resistance characteristics and physical properties of the plastic are included in the section.

Circle number (71) on reply card.

(72) COMPOSITE CATALOG

Minneapolis Honeywell Regulator Company has issued Catalog 5002, a composite catalog which briefly and concisely describes Honeywell industrial instruments and equipment, including the latest developments.

Circle number (72) on reply card.

(73) NEW MOTOR

U. S. Electrical Motors, Inc., has issued a multi-color 12-page booklet illustrating features of its Type H Uniclosed motor. Cut-open views of the motor, illustrating its various constructional features, are shown. The Type H is more compact than previous models, and an outstanding feature is its new fully protected design.

Circle number (73) on reply card.

(74) COOLING TOWER WOOD

"Cooling Tower Wood Can Be Protected" is the subject of Technical Paper No. 130, prepared by W. H. & L. D. Betz.

Deterioration of cooling tower wood has been a problem of increasing importance in industry in the last few years and this paper discusses how chemical and bacteriological attack can be controlled by acid treatment and wood preservatives to kill fungi.

Circle number (74) on reply card.

(75) MOTOR BUYING

A new 28-page catalog of buying information on a-c motors is available from the General Electric Company.

Designated GEC-1026, the bulletin presents complete buying information on standard a-c fractional and integral horsepower motors in most general use. Included are general-and definite-purpose fractional horsepower motors, and fhp gear motors.

Circle number (75) on reply card.

(76) SEALTIGHT COVERING

W. R. Meadows, Inc., announces a brochure covering its Sealtight Shield—a sturdy, flexible asphalt mastic board manufactured in job specified sizes. Sealtight Pipe Shield is scored every inch and company says is easily formed and strapped to pipe.

Circle number (76) on reply card.

(77) ELECTRONIC COMPUTER

A high performance, moderately priced electronic computer that is capable of solving lengthy and complex problems is now in production at the Bendix Computer division, Bendix Aviation Corporation.

Computer incorporates an improved two-address command structure providing for addition, subtraction, multiplication and divison as well as branching and other logical operations.

Circle number (77) on reply card.

(78) VERTICAL MOTORS

Construction features of Allis-Chalmers open-type vertical hollow shaft motors for outdoor service in ratings from 2-to-125 hp are described in a new bulletin released by the company.

Features of the motor include thrust bearing at the top for easy maintenance, a ventilation and cooling system of generous capacity, enclosed couplings and bearings, easily accessible parts, bearing housing designed for protection against deterioration during long periods of idleness in all kinds of weather, and a double insulated stator.

Circle number (78) on reply card.

(79) GRATING CATALOG

Bulletin No. 2486, a grating catalog, describes the types, sizes and load characteristics of complete line of electroforged steel and interlocked aluminum grating manfactured by the Blaw-Knox Company.

Circle number (79) on reply card.

(80) BEARINGS

Bulletin SF-82, published by Roller Bearing Company of America, describes its sealed pitchlign bearing. This is an outgrowth of the widely accepted pitchlign roller bearing. Outstanding characteristics of this bearing are described.

Circle number (80) on reply card.

(81) PLANT DESIGN

Economy in land, construction and material costs of a petroleum refinery, and how the complex elements of a refinery can be reduced to a simplified system, is the subject of the current issue of "Kellogram," published for the petroleum and chemical industries by The M. W. Kellogg's "In-line" system of plant design.

Circle number (81) on reply card.

(82) COAX

"How to Use the World's Smallest, Lightest Coax" is the subject of a new four-page illustrated folder titled "This is Microdot" now available from the Microdot.

Circle number (82) on reply card.

(83) TEMPERATURE CONTROL

"Temperature Control Systems," on application of automatic control to industrial process applications is available from Barber-Coleman Company.

One section is designed to aid in selection of sensing elements and their correct use for the most satisfactory results.

Circle number (83) on reply card.

(84) FASTENINGS

Ingersoll-Rand has issued "Impactools" devoted to running nuts, bolts, cap screws, and other types of fasteners. Case histories substantiate company claims that its lightweight Air Impactools are the answer to reducing fastening costs.

Circle number (84) on reply card.

(85) CENTRIFUGAL PUMPS

B. F. Goodrich Chemical Company's four-page article reprint describes installation of sealless Chempump centrifugal pumps at Avon Lake Experimental Station of B. F. Goodrich Chemical Company. Operating histories, installation details, and specific operating advantages of pumps are given.

Circle number (85) on reply card.

(86) HYSTAWAY CRANE

A 20-page brochure describing the Hyster Hystaway excavator-crane mounted on new or used Caterpillar D6, D7, or D8 track-type tractors is available. The well illustrated booklet explains on-the-job advantages of the Caterpillar-built tractor with dozer blade and Hystaway which can be quickly converted to either shovel, backhoe, dragline, crane, clamshell, or pile driver.

Circle number (86) on reply card.

(87) VERTICAL SEPARATORS

Black, Sivalls & Bryson, Inc., has announced publication of a 24-page catalog 30-01 on vertical separators, equipment designed to separate free gas and solution gas from the crude oil stream at the wellhead. In addition to perspective, cutaway, and dimensional drawings for low, intermediate, and high pressure sizes, the catalog features a section, "Sizing BS&B Vertical Separators."

Circle number (87) on reply card.

(88) PILOT PLANT

Patterson-Kelley Co., Inc.,East Stroudsburg, Pennsylvania, is offering a new product data sheet on its 5-gallon distillation pilot plant. Consisting of a reactor, agitator, condenser, and decanter, this standard unit can be used to study hundreds of chemical processing operations.

Circle number (88) on reply card.

(89) CHEMICAL FLOCCULATION

Proportioneers, Inc., division of B-I-F Industries, Inc., has reprinted an article on "Chemical Flocculation of Refinery Waste" in the form of an applications manual on petroleum refining.

Circle number (89) on reply card.

(90) DETECTING INSTRUMENTS

An operating manual for pipe detecting instruments has been printed by the Detectron Corporation. Although written chiefly for the Detectron Model 505, the manual contains operating hints and other information useful with any make of pipe detector.

Circle number (90) on reply card.

(91) THERMOSTATS

General Controls Company has graphically presented information on room thermostats in a six-page brochure designed to aid architects, builders, and appliance manufacturers.

Circle number (91) on reply card.

(92) STEAM TURBINES

The Steam Turbine division of Worthington Corporation has issued a new bulletin on single-stage steam turbines with steel casing construction. A cutaway view of a typical unit is shown, pointing out the standard features.

Circle number (92) on reply card.

(93) CHEMICAL FEEDERS

Proportioneers, Inc., division of B-I-F Industries, Inc., Providence, R. I., has issued a bulletin on "The Chlor-O-Mite — Low Capacity Chemical Feeders, Models E and H." This two-page color bulletin shows the feeders and typical arrangements for constant rate, intermittent, flow-proportional and hydraulic pulse feeding.

Circle number (93) on reply card.

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...to maintain maximum capacity!
Here are Discs that are strong, dense, light and resistant to the corrosive action of many chemicals.
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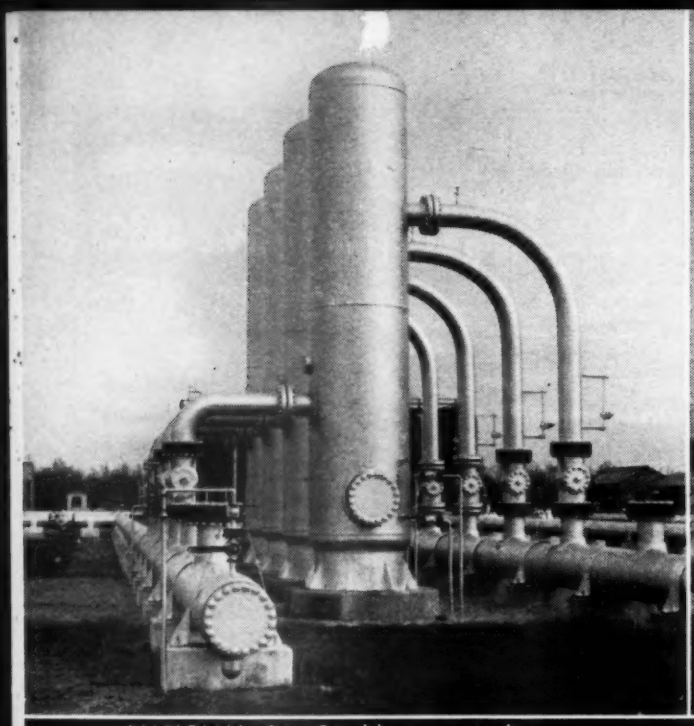
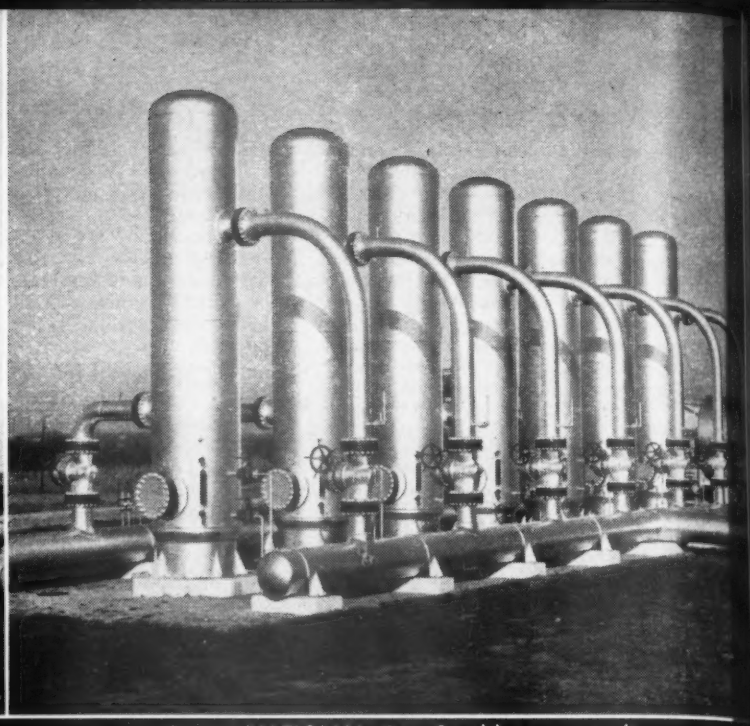
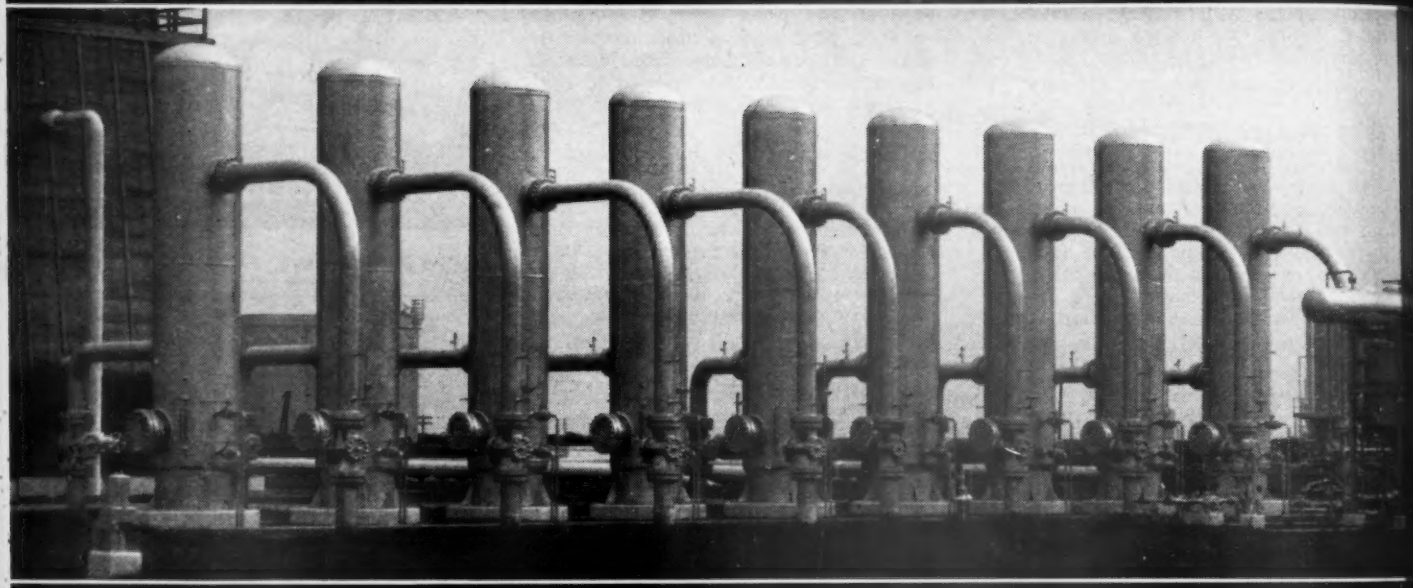


NATIONAL Gas Scrubbers, main line gas booster station, Batesville Miss.



NATIONAL Gas Scrubbers, main line gas booster station, Monroe, La.



NATIONAL Gas Scrubbers, main line gas booster station, Banquitte, Texas

NATIONAL WET-TYPE SCRUBBERS

54" O.D. x 20' — 750 PSI MAX. WP.
90 MM CU. FT./DAY. 12" INLETS AND OUTLETS

The service required of Wet-Type Scrubbers! Pipe line dust and other foreign materials are removed ahead of compressors at each pressure boosting station. This is done best by passing the gas through a special oil bath in a National Wet-Type Scrubber, then removing the liquid particles from the gas stream when passing through the National Gas Scrubbing element in the top part of the Scrubber.

National Vertical and Horizontal Gas Scrubbers are available in a wide range of sizes, working pressures and capacities to fit the needs of gas producers and carriers.

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XUM